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Developing supply chain for consumer products: Case study in a Finnish utility company

Master's Thesis

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Aalto University School of Science Master's Programme in Industrial Engineering and Management	ABSTRACT OF THE MASTER'S THESIS	
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Purpose
This master's thesis studies how a non-manufacturing firm should design and manage a supply chain for consumer products in a global environment where the firm has limited experience and competence on managing material flows to consumer customers. Existing literature on supply chain design and management is highly focused on manufacturing companies and thus, this study tries to fill this knowledge gap by addressing non-manufacturing companies with purchasing-intensive operations.

Methodology/approach
The study follows a problem-solving focused research approach, design science, by dividing the research into two main phases. First, a literature review is conducted focusing on the themes of supply chain design and management in order to highlight the major elements is prior research and to form a theoretical foundation for the practical solution. Second, a case study is conducted in a Finnish utility company to develop, test and evaluate the solution's applicability in the context of the case company.

Findings
Research indicates that supply chain design process starts by analyzing product types, customer needs and marketplace requirements, and linking the supply chain strategy and type to the firm's context. It was found that a supply chain combining lean and agile, leagile, was most suitable for the case company. After determining the supply chain type, the actual supply chain structure is formed. A primary decision factor is the degree of logistics postponement which determines the number and location of warehouses and distribution channel choices in the supply chain. Finally, supply chain management must be ensured by defining the basic processes and the required level supply chain integration with external actors.

Practical implications
The proposed solution provides concrete guidelines and decision factors related to supply chain design and management to be utilized in a purchasing-intensive supply chain environment solving the case company's problem. Additional benefits for the case company include increased supply chain understanding, more efficient and simple material flows, and probable operational performance improvements.

Scientific value
Research partly confirms existing theory by showing that certain elements in traditional supply chain design and management theory can also be applied in a purchasing-intensive environment lacking manufacturing operations. In addition, research identifies elements and decisions factors that are relevant especially for non-manufacturing companies such as the high focus on inventory management.

Keywords: supply chain design, supply chain management, logistics, consumer products

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Tarkoitus
Diplomityö tutkii miten hankintaan keskittyvän yrityksen tulisi suunnitella ja hallita toimitusketjuaan ympäristössä, jossa sillä ei ole aikaisempaa kokemusta tuotteiden toimittamisesta kuluttaja-asiakkaille. Aikaisempi tutkimus toimitusketjun suunnittelun ja hallinnan alueilla on painottunut valmistaviin yrityksiin, joten tutkimus pyrkii luomaan uutta tietoa tutkimalla yrityksiä, joilla ei ole omaa valmistusta ja näin keskittyen valmiiden tuotteiden hankintaan toimittajilta.

Menetelmät
Tutkimus noudattaa suunnittelutieteen (design science) lähestymistapaa pyrkien ratkaisemaan yrityksen konkreettisen ongelman ratkaisuehdotuksella. Tutkimusprosessi aloitettiin kirjallisuuskatsauksella keskittyen pääosin toimitusketjun suunnitteluun ja hallintaan liittyvään kirjallisuuteen tavoitteena tunnistaa tutkimusalueen pääteemat sekä luoda teoreettinen pohja ratkaisuehdotukselle. Tutkimuksen toinen vaihe suoritettiin tapaustutkimuksena suomalaisessa yrityksessä, missä ratkaisuehdotusta kehitettiin edelleen ja lopulta sen toimivuutta arvioitiin tapausyrityksen kontekstissa.

Tulokset
Tutkimus osoittaa, että toimitusketjun suunnittelu tulee aloittaa tuotetyyppien, asiakastarpeiden sekä toimintaympäristön analysoinnilla. Lisäksi on tärkeää, että toimitusketjustrategia ja -tyyppi linkitetään aina yrityksen kontekstiin. Tehokasta (lean) ja ketterää (agile) yhdistävän toimitusketjutyypin havaittiin olevan paras ratkaisu tapausyritykselle. Toimitusketjutyypin valitsemisen jälkeen määritetään ketjun varsinainen rakenne, joka hankintaan keskittyvillä yrityksillä liittyy vahvasti siihen kuinka paljon logistiikkaa viivästytetään. Viivästyttämisen aste pääosin määrittää varastojen määrä ja paikan sekä jakelukanavat toimitusketjussa. Viimeisenä on määritettävä prosessit toimitusketjun hallintaan sekä missä määrin on tarpeen tehdä yhteistyötä yrityksen ulkopuolisten toimijoiden kanssa.

Käytännön arvo
Esitetty ratkaisu tarjoaa tapausyritykselle konkreettisia suuntaviivoja ja ohjeita toimitusketjun suunnitteluun ja hallintaan hankintaan painottuvassa toimintaympäristössä. Ratkaisu tarjoaa lisäksi yritykselle lukuisia käytännön hyötyjä kuten lisääntyneen toimitusketjutuntemuksen, tehokkaammat ja yksikertaisemmat materiaalivirrat sekä todennäköisesti kasvavan toimitusketjun suorituskyvyn.

Tieteellinen arvo
Tutkimus osaltaan vahvistaa olemassa olevaa teoriaa näyttäen, että valmistaviin yrityksiin keskittyvää teoriaa ja malleja voidaan hyödyntää myös hankintaan keskittyvässä toimitusketjussa. Lisäksi tutkimus tuottaa uutta hyödyllistä tietoa mitkä elementit ja kriteerit ovat erityisen tärkeitä nimenomaan hankintaan keskittyville yrityksille ilman omaa tuotevalmistusta.

Asiasanat: toimitusketjun suunnittelu, toimitusketjun hallinta, logistiikka, kuluttajatuotteet

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Terminology

Agile supply chain

Agile supply chain is a type of supply chain focusing on the interface between a company and the market. Agile supply chains profit by responding to rapidly changing, continually fragmenting global markets by being dynamic and context-specific, aggressively changing, and growth oriented. (Vonderembse et al. 2006 p. 227)

Distribution

Distribution considers the activities of moving and storing products from manufacturers to the final customers integrating various actors such as manufactures, distributors, retailers and customers. (Chopra 2003 p. 123)

Lean supply chain

Lean supply chain is a type of supply chain employing continuous improvement efforts that focus on eliminating waste or non-value steps along the chain in order to achieve cost efficiencies. (Vonderembse et al. 2006 p. 227)

Logistics postponement

Logistics postponement is a logistics strategy where changes in the inventory location downstream in the supply chain are postponed to the last possible point. (Pagh & Cooper 1998 p. 14)

Manufacturing postponement

Manufacturing postponement, also referred to as *production postponement*, is a manufacturing strategy where the product is maintained in a neutral and uncommitted form by postponing the differentiation to the latest possible point in the supply chain. (Pagh & Cooper 1998 p. 14)

Order decoupling point (ODP) / Order penetration point (OPP)

Order decoupling point, also referred to as *order penetration point*, is the point in the supply chain where product is linked to a specific customer. (Olhager 2003 p. 320)

Product life cycle

Product life cycle illustrates the change in product's sales volume when time progress including four phases: introduction, growth, maturity and decline. (Christopher 2011)

Reverse logistics

Reserve logistics is the "role of logistics in product returns, source reduction, recycling, materials substitution, reuse of materials, waste disposal and refurbishing, repair, and remanufacturing". (Stock 1998)

Supply chain

Supply chain is "the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services delivered to the ultimate customer". (Christopher 2011)

Supply chain integration

Supply chain integration is defined as the "degree to which a firm strategically collaborates with its supply chain partners and collaboratively manages intra- and inter-organization processes". (Flynn et al. 2010 p. 59)

Supply chain management

Supply chain management is the "process of planning, implementing, and controlling the efficient flow and storage of raw materials, in-process inventory, finished goods and related information flow from point-of-origin to point-of-consumption for the purpose of conforming to customer requirements". (Council of Logistics Management 1986)

1 Introduction

The purpose of this master’s thesis is to study how a supply chain should be designed and managed for consumer products in an environment where the organization’s traditional core competence does not include handling material flows to consumer customers. The problem is approached using a problem-solving focused design science research approach combined with a case study in Finnish utility company. This chapter begins by motivating the importance of the research topic and providing a short overview on existing literature around the topic. Next, the case company is briefly introduced which is followed by presenting the research problem and questions for the study. Finally, objectives and scope for the research are discussed in the last section of this chapter.

1.1 Background and motivation

Global operations and presence of organizations in many continents have become common especially during the 21th century due to globalization and increased trend of outsourcing activities to low-cost countries, for example, in Asia. Thus, supply chains have evolved from being country-specific in the past to global supply networks including activities and actors in different geographical areas and continents. This has significant implications for supply chain design and management since by effectively designing and managing their supply chains, organizations can achieve competitive advantage both in terms of cost and service level compared to their competitors (Mentzer et al. 2001). Christopher (2011) has addressed the importance of supply chains by stating that “it is supply chains that compete, not companies”.

Important aspect in any supply chain is to tailor the structure and operations based on the requirements set by the environment and marketplace (Fisher 1997). This was first addressed in the manufacturing environment as the need for focus in the manufacturing process was emphasized in order to overcome conflicting objectives between company’s functions (Skinner 1974). The same thinking was later extended to cover logistics when Fuller et al. (1993) highlighted tailored logistics for enabling companies to serve customer segments differing in their service level requirements. Finally, the need for focus was applied in the context of complete supply chains by Fisher (1997) arguing that supply chain must be matched to the supplied product type in order for it to be effective and competitive.

Existing literature related to supply chain design and management is highly focused on manufacturing companies and thus, involving key decisions about production capacity, production schedule and quantity as an essential management area of the supply chain. In addition, majority of the case studies in this research area have been conducted in manufacturing companies. Thus, there is an extensive amount of research available how manufacturing firms should design and manage their supply chains. However, what is lacking in the literature, is the focus on non-manufacturing companies that rely completely on purchasing ready-made components and products and thus, combine sourced materials and products into unique product offerings for customers.

In addition, majority of the research and case studies in field of supply chain design and business process re-engineering have been conducted in companies that already are experienced in handling material flows to consumer customers. Thus, there is a knowledge gap how a company not experienced in consumer customer material flows should approach supply chain design and management. This study tries to fill in this knowledge gap by investigating supply chain design and management for non-manufacturing firms with purchasing-focused supply chain operations in an environment where experience on handling material flows to consumer customers is limited.

1.2 Introduction to case company

The case company in this thesis is a Finnish utility company operating in the energy industry offering electricity, heating and cooling, and complete energy and waste management solutions for cities and municipalities. The main market areas of the case company are in the Nordics, Russia, Poland and the Baltic countries. In the recent years, the company has expanded into new markets and grown through several acquisitions and mergers. Organizational structure consists of several business divisions and two development units that are responsible for their own business areas. In addition to these, corporate functions, such as procurement, IT and finance departments, support the business divisions and units in their daily activities.

To strengthen its position in the changing energy market and to promote energy efficiency and sustainability concerns, the case company has started to offer tangible products to consumer consumers in addition to electricity and heating. These products are related to home energy management and efficiency including solar systems for households, electric vehicle chargers, batteries, smart home products, and solutions for electricity consumption and heating management. A common characteristic of these products is that they require an electrical installation performed by a certified electrician at the customer's house due to regulation and safety reasons. Since the case company offers all products as turnkey packages, management of material suppliers, logistics service providers and installation service providers in the supply chain is required to offer high-quality service to the customers.

1.3 Research problem and questions

Existing literature related to supply chain design and management focuses heavily on manufacturing firms with previous experience and competence on handling material flows to consumer customers. However, research in the field of purchasing-focused companies with limited experience on handling material flows is more uncommon. Since effective supply chain design and management are crucial to compete in today's environment, more knowledge and insight is needed for non-manufacturing companies. This study tries to fill in this knowledge gap by investigating supply chain design and management for non-manufacturing companies in a global environment where experience and competence on handling material flows to consumer customers are lacking. Thus, the following main research question and sub-questions are presented:

- How to design and manage a global supply chain for consumer products?
    - How to do this in an environment where the organization lacks experience on handling material flows to consumer customers?
    - What are the implications of purchasing-intensive operations?

1.4 Scope and objectives for the research

The aim of this research is to study the design and management of a supply chain for consumer products by identifying the basic elements in supply chain design and practices needed for effective supply chain management. Thus, the focus is more on the strategical level rather than focusing on operational problems such as exact facility location and quantity related decisions. In addition, the research is especially focused in designing and managing the supply chain in a business environment that is new for the organization and thus, the organization is lacking expertise and knowledge in the area.

The case study was conducted in a Finnish energy utility company and the empirical part is limited to this one company. The case company has no own production activities and thus, production-related activities and decisions are not considered in the empirical part of the study. This means that most focus is on purchasing, transportation, inventory management and distribution activities in the supply chain. The objectives for the study are:

- Identify basic elements and decisions in supply chain design and management
    - Appropriate supply chain strategies in each environment
    - Different options for supply chain structure and distribution pipeline
    - Key processes and activities for supply chain management
- Evaluate effects of a specific business and supply chain environment
    - Purchasing materials and ready-made products instead of manufacturing
    - Lack of expertise and competence on material flows to consumers

1.5 Structure of the thesis

The thesis consists of three main parts: a literature review in part I, an empirical study presented in part II and contributions set out in part III. Literature review was conducted in order to increase the understanding about the research topic and to form a theoretical foundation for the empirical part of the study. Empirical part describes the research methods used in the empirical study and presents the actual empirical findings. In the final part, both practical and theoretical contributions of the study are discussed. In addition, the limitations of the study are evaluated and directions proposed for further research.

Part I - Literature review

2 Research method for literature review

Main areas included in the literature review were supply chain design and configuration, and supply chain management, which are discussed in chapters 3 and 4. Primary literature sources were journal articles published in recognized academic journals such as *International Journal of Production Economics*, *The International Journal of Logistics Management*, *Journal of Business Logistics*, *Journal of Operations Management* and *Journal of Supply Chain Management*. In addition to academic journals, few textbooks, and other kind of publications were utilized in the review. Literature was searched mainly using Google Scholar and Web of Science with key word searches related to the majors themes introduced above. In addition, interesting sources were also identified based on upwards and downward citation paths when a key literature source was found.

Supply chain design and configuration is first discussed in chapter 3 which consist of decisions about the supply chain structure in a higher strategical level. Major elements in structural decisions are related to the product type and requirements posed by the market. In addition, the importance of linking the supply chain strategy and structure to customer needs is discussed. In the core of this section, are lean and agile supply chain types and their suitability to different situations, products and marketplaces.

The second major focus area in the literature review, supply chain management, is discussed in chapter 4. Chapter begins by providing a general overview on supply chain management as a concept by discussing its meaning, purpose and objectives. This is followed by introducing the supply chain operations reference (SCOR) model and highlighting some of the key supply chain management activities including transportation, inventory management, distribution, reverse logistics and supply chain performance measurement. In addition, the concept of supply chain integration is introduced and its importance motivated in the end of the chapter. Finally, literature synthesis is formed in chapter 5, which is the theoretical background and foundation for the empirical part of the study.

3 Supply chain design and configuration

This chapter discusses supply chain design and configuration decisions on a strategical level. These decisions include the structure of the supply chain and which supply chain strategies should be used for a particular situation, product or marketplace. The underlying argument is that supply chain strategy and configuration should be matched to the market conditions and product type that is supplied in the chain. Product types and market requirements are first discussed in chapter 3.1 followed by introducing the most common supply chain types in chapter 3.2. Chapter 3.3 links these two themes together by discussing what supply chain types are appropriate in certain situations and how two supply chain types, lean and agile, can be combined within a single supply chain. Finally, the impact of product life cycle phase on supply chain strategy is discussed in chapter 3.4.

3.1 Product types and market requirements

One of the early pioneers to study product types and suitable supply chains was Fisher (1997) when he argued that supply chain structure must be matched to the product type. According to Fisher, many supply chain problems are due to the mismatches between the product and supply chain type. He classifies products as either functional or innovative. Functional products (also referred as standard products) are products that satisfy basic customer needs which do not change often and thus, products have stable and predictable demand and long product life cycles. In addition, profit margins for functional products are low and there are few product variants. Examples of functional products include staples or canned beans. Innovative products (also referred as fashion products), however, are the opposite of functional products since their demand is highly volatile and very unpredictable, and product life cycles are short. Profit margins are higher and product variety can be measured even in millions per product category. Women clothing or PCs are common examples of innovative products (Fisher 1997). Table 1 summarizes the main characteristics of functional and innovative products.

Table 1. Characteristic of functional and innovative products (Fisher 1997)

	Functional product	**Innovative product**
Demand	Stable and predictable	Volatile and unpredictable
Product life cycle	Long (over 2 years)	Short (3-12 months)
Profit margin	5-20%	20-60%
Product variety	Low (10-20 variants)	High (millions)
Average margin of error in forecast	10%	40-100%
Average stock-out rate	1-2%	10-25%
Made-to-order lead time	6-12 months	1-14 days

Since there are not many products in the real world that can be classified completely as a functional or an innovative product, researchers have also introduced a concept of hybrid product (Huang et al. 2002, Vonderembse et al. 2006). These kind of products are usually products with modular design consisting of a mixture of standard and innovative components (Huang et al. 2002). Typically hybrid products are large purchases made periodically by the customers requiring careful investigation and consideration before the purchase. One example of hybrid products are cars which are assembled based on orders to fulfill specific customer needs and requirements. (Vonderembse et al. 2006)

In addition to product types, requirements set by the market and customers are important related to supply chain strategy. Four basic manufacturing strategy metrics have been proposed (Hill 1993), which can be also used in the supply chain context (Mason-Jones et al. 2000b). These include price, quality, lead time and service level. It must be emphasized that all of these criteria are not by default equally important for a given product. In order to be competitive in the market, company's product must fulfill the minimum level of market qualifier (MQ) criteria but, in order to win the actual customer orders, market winner (MW) criteria must the best among the competitors. (Hill 1993)

	Market qualifiers	Market winners
Innovative products	Quality Price Lead time	Service level
Functional products	Quality Lead time Service level	Price

Figure 1. Market qualifiers and winners per product type (Mason-Jones et al. 2000b)

As it was already mentioned, market qualifiers and winners differ between product types. Mason-Jones et al. (2000b) have presented a matrix presented above in Figure 1 that illustrates these differences. For innovative products, availability in terms of service level is the market winner while quality, price and lead time are the market qualifiers. However, for functional products, the key market winner is price and market qualifiers include quality, lead time and service level. (Mason-Jones et al. 2000b)

To conclude, products can be classified into three types: functional, innovative and hybrid products. Each product type have its own key characteristics based on for example demand predictability, production lead times and product life cycles. In addition, it was identified that each product type have unique success criteria defined as market qualifiers and winners that determine their competitive position in the market.

3.2 Supply chain types

In addition to defining the two product types, Fisher (1997) suggested that it is important to consider the type of the supply chain, either efficient or responsive, to be used with a particular product. These two supply chain types are summarized in Table 2. According to Fisher (1997), the primary purpose of an efficient supply chain is to supply predictable demand and, at the same time, achieve the lowest possible supply chain cost. In addition, inventory turns should be high and inventory levels minimized throughout the whole supply chain. Lead times should be shortened until to the point which minimizes costs. Responsive supply chain, on the other hand, focuses on responding to rapid and fast changes in the market and customer needs. Buffer inventories should be maintained and efforts to lead time reduction should be high in order to enable fast responses to changing demand. (Fisher 1997)

Table 2. Characteristics of efficient and responsive supply chains (Fisher 1997)

	Efficient supply chain	Responsive supply chain
Primary purpose	Supply predictable demand with lowest possible cost	Fast response to unpredictable demand
Manufacturing focus	High average utilization rate	Maintain buffer capacity
Inventory strategy	High turns and minimize	Maintain buffer stocks
Lead time focus	Shorten while minimizing cost	High efforts to reduce
Supplier selection criteria	Cost and quality	Speed, flexibility and quality
Product design strategy	Maximize performance and minimize cost	Modular design

Efficient and responsive supply chains are often also called lean and agile supply chains respectively (Naylor et al. 1999). Lean supply chain involves building a value chain that eliminates all waste or, in other words, eliminates all non-value adding steps in the chain including for example waiting times and inventories. In addition, level schedules and high capacity utilization in manufacturing activities are essential for lean supply chain. (Naylor et al. 1999) Economic production of small quantities is achieved by seeking setup time reductions and internal manufacturing efficiencies (Vonderembse et al. 2006). However, since lean mostly focuses in achieving efficiencies in production, lean supply chain might lack the external responsiveness to customer demand. Responsiveness requires flexibility in several key activities in addition to production such as product design, scheduling and planning, and distribution. (Booth 1996) In this case, agile supply chain is more suitable.

Agility related to manufacturing and supply chain strategies can be defined as using market knowledge and virtual organizations to take advantage of profitable opportunities in a volatile and uncertain market (Naylor et al. 1999). In other words, agile supply chain focuses in flexibility enabling the chain to respond to sudden changes in the marketplace e.g. to changing demand. Thus, fast deliveries and lead time flexibility are required in achieving these goals. Agile supply chain uses information systems and technologies to enable fast and effective communication and decision-making. In addition, decision-making is pushed down the organization since more emphasis is placed on organizational issues and employees. (Vonderembse et al. 2006)

What truly differentiates agile and lean supply chains is the variability in demand and thus, the circumstances where they can be most effectively applied (Childerhouse & Towill 2000). High levels of quality are important for both types as well as short lead times to satisfy customer demand. However, the reasoning behind lead time reduction differs. In a lean supply chain, time is seen as a waste and thus, it should be minimized. Agile supply chain, on the other hand, requires minimal lead times to supply volatile customer demand as quickly as possible. Also customer drivers are different since lean supply chain focuses on the lowest possible cost leading to low price and agile supply chains compete in availability (Childerhouse & Towill 2000). One additional difference between the two types is the manufacturing strategy and related capacity decisions. Agile supply chain must be robust in order to handle variations and disturbances, and one method to achieve this is to invest in excess and flexible production capacity. In contrast, the objective in lean supply chain is to achieve level production schedules and to maximize capacity utilization. (Naylor et al. 1999) Agile and lean supply chains are summarized below in Table 3.

Table 3. Attributes of agile and lean supply chains (Mason-Jones et al. 2000a)

Attribute	Lean supply chain	Agile supply chain
Demand	Predictable	Volatile
Product variety	Low	High
Product life cycle	Long	Short
Profit margins	Low	High
Dominant costs	Physical costs	Marketability costs
Purchasing policy	Buy goods	Assign capacity
Information enrichment	Highly desirable	Obligatory
Forecasting method	Algorithmic	Consultative
Market qualifiers	Quality, lead time, service level	Quality, price, lead time
Market winners	Price	Availability/service level

As it was discussed in the previous section, products can be classified as hybrid in addition to functional and innovative products. The same logic applies to supply chain types and a hybrid supply chain has been proposed to accompany lean and agile supply chains (Huang et al. 2002, Vonderembse et al. 2006). Hybrid supply chains utilize practices and methods from both lean and agile supply chains, and typically involve assemble-to-order (ATO) products enabling mass customization through postponing the final assembly by using modular product design as the foundation (Huang et al. 2002, Vonderembse et al. 2006). Naylor et al. (1999) have also referred this hybrid approach as "leagility" since it combines the best elements of lean and agile methods.

Regardless of the supply chain type, there is always system-induced uncertainty present in the supply chain which must be reduced. In other words, certain problems and inefficiencies are causes by the supply chain system itself for example due to the lags in information flow or ineffective supply chain structure. (Mason-Jones et al. 2000b) One classical example is the Bullwhip effect originally proposed by Forrester (1961) which describes the dynamics in the supply chain. According to the Bullwhip effect, small variations in demand at the customer are amplified when moving upstream in the supply chain towards suppliers due to delays in communication and different ordering policies (Forrester 1961). System-induced uncertainty can be removed by simplifying material flows in the supply chain (Mason-Jones et al. 2000b).

Towill (1999) has proposed twelve rules for simplifying and streamlining material flows in the supply chain which are further divided into four material flow control principles by Mason-Jones et al. (2000b). These are (1) selection of good decisions support systems, (2) reduction of material and information flow lead times, (3) availability and sharing of high-quality operations information and (4) elimination of redundant echelons in the supply chain.

3.3 Matching supply chain to product and market

After describing different product and supply chain types, discussion continues on how the supply chain type should be matched to the product type and, at the same time, taking market and customer requirements into account. Several researches have addresses the key point that the supply chain type need to be matched to the product type and market environment (Fisher 1997, Mason-Jones et al. 2000b, Vonderembse *at al*. 2006). Thus, it seems clear that “one size does not fit all” (Shewchuk 1998). This topic of matching supply chain to the product and market is discussed next.

Fisher (1997) concludes that efficient (lean) supply chain is best matched with functional products and responsive (agile) supply chains suits best for innovative products as presented in Figure 2. Otherwise, there will be a mismatch between the product and supply chain type and it is very likely that the company faces problems in its operations. Most typical mismatch is that the company is trying to supply innovative products with an efficient supply chain and face problems since the supply chain is not able to cope with the responsiveness required by the market. Options in this situation are to make the product more functional or to develop the supply chain towards more responsive. Fisher’s framework provides the first guidance how companies can formulate an ideal supply chain strategy based on their product requirements. (Fisher 1997)

	Functional products	**Innovative products**
Efficient supply chain	Match	Mismatch
Responsive supply chain	Mismatch	Match

Figure 2. Framework for matching product and supply chain type (Fisher 1997)

The framework of Fisher (1997) have been extended by adding product replenishment lead time and thus, classifying supply chains based on three variables: product type (standard or innovative), demand (stable or volatile) and lead time (short or long) (Christopher & Towill 2002b). Christopher, Peck & Towill (2006) have simplified the classification framework of Christopher & Towill (2002b) by combining product type and demand variables using the insight that standard products usually have stable and predictable demand and, on the other hand, demand for innovative products is typically volatile and unpredictable. Thus, product type and demand characteristics are interrelated and can be combined into a single variable. As a result, Christopher & Towill (2002b) propose four generic supply chain strategies based on replenishment lead time (short or long) and demand type (predictable or unpredictable) as presented in Figure 3.

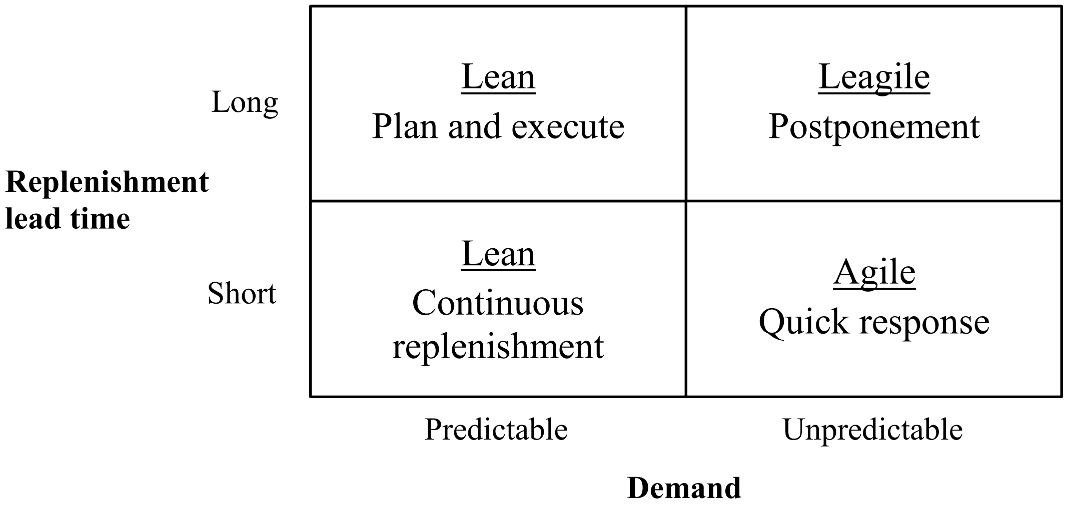


Figure 3. Supply chain classification by lead time and demand type (Christopher & Towill 2002b)

When replenishment lead times are short and demand predictable, continuous replenishment strategy might be the most applicable. This strategy involves inventory replenishment on a more continuous basis with small and frequent replenishment orders, also enabling the use of vendor-managed inventory (VMI). However, when there are long replenishment lead times and predictable demand, lean methods can be used by planning and sourcing ahead of demand in the most efficient way. Effective utilization of this strategy requires sufficient demand data, prior experience and forecasting capability to avoid supply risks. Postponement is a suitable strategy in a situation where lead times are long and demand unpredictable. Strategic inventory of generic components and modules is maintained and products are assembled and distributed according to customer orders. Finally, agile methods are most appropriate with short lead times and unpredictable demand with the goal of responding to the changing environment as quickly as possible. (Christopher & Towill 2002b)

Fisher's (1997) and Christopher & Towill's (2002b) frameworks propose that either lean or agile supply chain should be used in most of the cases. However, some researchers have proposed that lean and agile supply chains can be combined in every situation and thus, "getting the best from both worlds" (Christopher & Towill 2001, Naylor et al. 1999). A time/space matrix can be used to illustrate different methods to combine lean and agile as presented in Figure 4 (Christopher & Towill 2002a). Three alternatives for combining lean and agile are then identified (Christopher & Towill 2001):

- Pareto curve approach (different space/same time)
- Decoupling point approach (different space/different time)
- Separating base and surge demand (same space/different time)

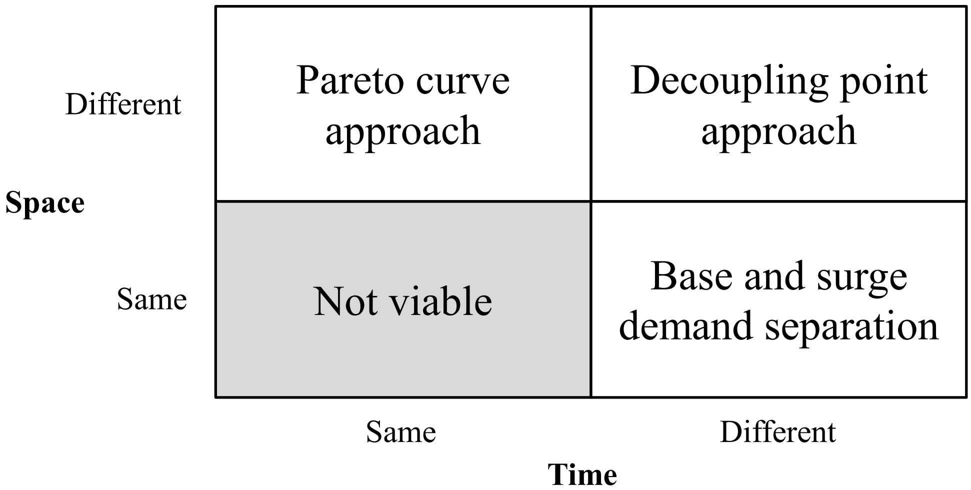


Figure 4. Time/space matrix of combining lean and agile (Christopher & Towill 2002a)

Pareto curve approach in the top-left corner of the matrix runs two separate supply chain processes in parallel. It has been showed that companies who manufacture or distribute a wide range of products can use the Pareto Law when determining their supply chain strategies (Christopher & Towill 2001). In practice, this rule means that 80% of the total volume is generated by 20% of the product line. Thus, different supply chains strategies are required for fast and slow moving products. Christopher & Towill (2001) suggest that the top 20% of products (80% of volume) have more predictable demand and thus, lean manufacturing and distribution can be used. In addition, manufacturing should be operating based on forecasts, inventories managed centrally and economies of scale utilized. However, the remaining 80% of products (20% of volume) should be managed with agile methods since their demand is most likely less predictable. This includes making products to order, utilizing quick response and continuous replenish concepts, and forecasting capacity requirements. (Christopher & Towill 2001) To summarize, Pareto curve approach works best when product variety is high and demand is non-proportionate across the product range.

Lean and agile supply chains can also be combined by positioning the order decoupling point (also referred to as order penetration point, OPP (Olhager 2003)) in a suitable position enabling the supply chain to respond to volatile demand downstream towards customers and, at the same time, enabling level scheduling and efficiencies upstream towards suppliers. Order decoupling point (ODP) is defined as the point in the supply chain to which the customer's order penetrates (Hoekstra and Romme 1992). Thus, supply chain operations upstream from ODP are forecast-driven and material is pushed to the ODP. However, downstream from ODP, supply chain is operating in a demand-driven mode or, in other words, products are pulled by the customers (Hoekstra and Romme 1992, Naylor et al. 1999). Naylor et al. (1999) terms this combination of lean and agile supply chain types as "leagile" since it combines lean processes upstream from the decoupling point and agile processes downstream as presented in Figure 5.

ODP should be the point where strategic stock is held and customer demand supplied in the supply chain and thus, acting as the buffer between stable supply and unpredictable demand (Childerhouse & Towill 2000). Positioning of the decoupling depends primarily on two factors: longest lead time accepted and product variety required by the customers (Hoekstra and Romme 1992). In addition to ODP, companies should take into account the information decoupling point which is the furthest point upstream in the supply chain to which real demand information flows or, in other words, information that has not been distorted by inventory and ordering policies. This is important since supply chain agility is partly based on the ability to make replenishment decisions based on real demand. (Christopher & Towill 2001) Next, different positions for the ODP and resulting delivery strategies are discussed.

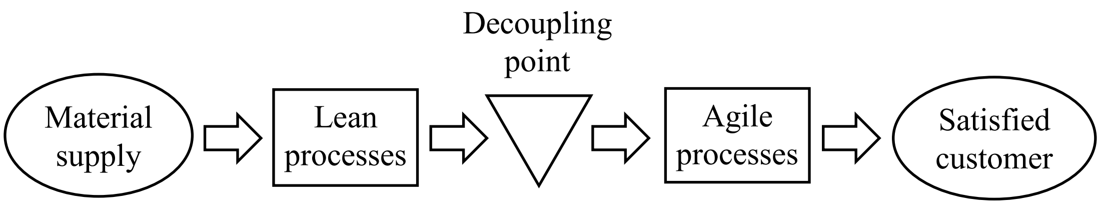


Figure 5. Combining lean and agile using order decoupling point (Mason-Jones et al. 2000a)

Four common product delivery strategies based on ODP position have been identified: engineer-to-order, make-to-order, assemble-to-order and make-to-stock (Olhager 2003). These four strategies and related ODP positions are presented in Figure 6. In engineer-to-order (ETO) environment, deliverables are designed from the beginning based on customer specifications and requirements. ETO delivery strategy is typically used with large, complex and project-based deliveries such as custom heavy machinery. Make-to-order (MTO) strategy manufactures products based on customer orders enabling high product variety and customization options. This option is viable when high product variety is required and customers are willing to accept long delivery times. Assemble-to-order (ATO), on the other hand, can be used when high level of customization is required with shorter lead times compared to MTO. ATO typically utilizes modular product design to enable high product variety and classical ATO product examples include PCs and cars. Finally, in the make-to-stock (MTS) delivery strategy, products are manufactured to stock based on forecasts and customers supplied from the finished goods inventories. MTS products typically have low product variety and stable demand. (Olhager 2003)

In addition to these four common strategies proposed by Olhager (2003), it also possible to postpone the purchasing (Yang et al. 2004) leading to a strategy between ETO and MTO. This strategy is termed as buy-to-order (BTO) and it places the ODP at purchasing. Thus, materials and components required for manufacturing are purchased based on customer orders. The strategy is most applied in an environment with highly uncertain demand or if components are very expensive making it impossible to hold component inventories. (Yang et al. 2004)

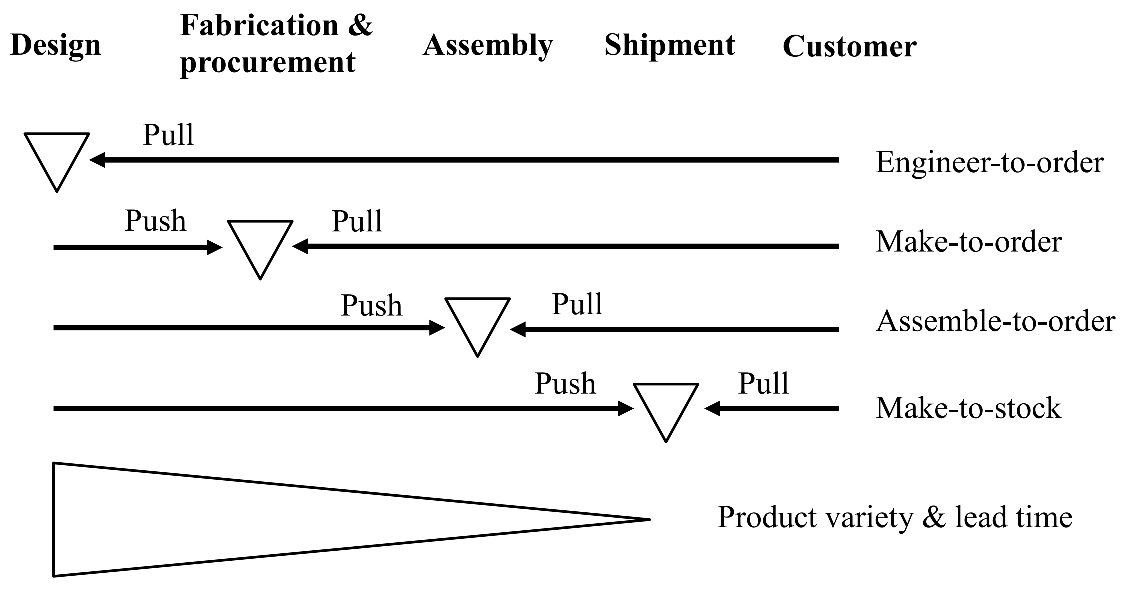


Figure 6. Different product delivery strategies based on ODP position (modified from Olhager 2003)

Third option to combine lean and agile supply chains is to separate demand pattern into two elements: base demand and surge demand (Gattorna & Walters 1996). Lean supply chain practices to obtain economies of scale can be applied to base demand since it can be forecasted using past demand data and experience. Surge demand, on the other hand, cannot be forecasted and thus, it requires more flexible, agile and typically higher cost processes. This methods is especially useful with seasonal demand and examples can be found in the clothing industry where base demand is sourced cost effectively overseas before the season and surge demand filled locally near the market during the actual selling season. (Christopher & Towill 2001) Base and surge demand separation works when past demand data is available and thus, base level demand can be confidently predicted and small-batch local manufacturing or material sources can be found.

3.4 Impact of product life cycle phase

Supply chain design and configuration decisions discussed above view the supply chain structure and product types as static that do not change over time. However, since this is rarely the case in the real world, researchers have also examined the effects of product life cycle phase on supply chain design and configuration (Aitken et al. 2003, Fine 2000, Vonderembse et al. 2006). According to this literature, supply chain design and operations have to linked to the product life cycle phase since the product type and market requirements might change depending on the product life cycle phase.

Product life cycle illustrates the change in product's sales volume when time progress as presented in Figure 7. The generic product life cycle includes four separate phases: introduction, growth, maturity and decline. The product is introduced at the beginning of the introduction phase and sales volumes increase slowly throughout phase. Next in the growth phase, sales volumes increase rapidly when the product has established its place in the market. Sales volumes increase until the maturity phase when demand reaches its peak and remains stable. Finally in the decline phase, product sales volumes start to decrease rapidly up until to a point when the product it taken out from the market. (Aitken et al. 2003, Christopher 2011)

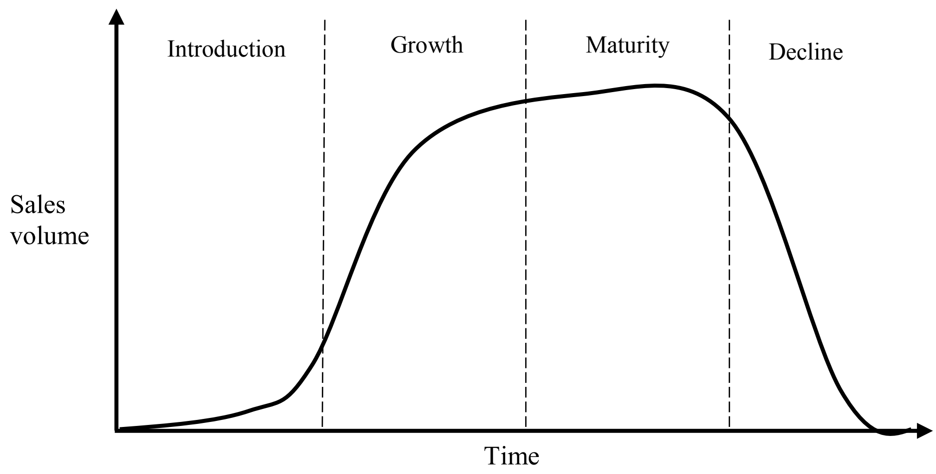


Figure 7. Generic product life cycle (Christopher 2011)

Vonderembse et al. (2006) link supply chain and products types also taking into account the product life cycle phase of the product. They propose that lean supply chain should be used for functional products in all life cycle phases. This is due to the fact that functional products have long product life cycles and stable designs, and their demand is predictable over the whole life cycle of the product. Thus, a lean supply chain with level scheduling can be used. However, innovative products require an agile supply chain in the introduction and growth phase since the demand in highly volatile both in terms of volume and variety. When an innovative product reaches the maturity phase, it has been firmly established in the market, demand becomes more predictable and the importance of price increases compared to availability. Thus, lean supply chain can be used with innovative products in the maturity and decline life cycle phases. Finally, Vonderembse et al. (2006) propose that hybrid supply chain should be used in all life cycle phases for hybrid products. Table 4 summarizes the appropriate supply chain types depending on product type and life cycle phase.

Table 4. Product type and life cycle phase supply chain classification (Vonderembse et al. 2006)

<table>
<tr><th>Product type /
Product life cycle</th><th>Standard</th><th>Innovative</th><th>Hybrid</th></tr>
<tr><td>Introduction</td><td rowspan="4">Lean supply chain</td><td rowspan="2">Agile supply chain</td><td rowspan="4">Hybrid supply chain</td></tr>
<tr><td>Growth</td></tr>
<tr><td>Maturity</td><td rowspan="2">Lean supply chain</td></tr>
<tr><td>Decline</td></tr>
</table>

Aitken et al. (2003) focus more concretely on the implications of the product life cycle phase on the manufacturing strategy. They studied an UK-based lighting manufacturer and proposed four distinct manufacturing strategies in the supply chain: design and build, materials requirements planning (MRP), Kanban and postponement. In the introduction phase when availability and capability are key orders winners in the market, design and build strategy is required where products are made to order based on unique customer requirements. Availability and the ability to respond to unpredictable demand are the key order winners in the growth life cycle phase. Thus, MRP approach with push material flows, shared manufacturing resources and raw material stocks is required at this phase. During the maturity phase when cost is the key order winner in the market, Kanban-based pull and production postponement strategies can be used to minimize costs and maximize product variety. Finally in the decline phase, the product in transferred back to the MRP approach in order to maximize service level with reasonable lead times when sales and production volumes decrease. (Aitken et al. 2003) Figure 8 illustrates these strategies mapped to the generic product life cycle phases.

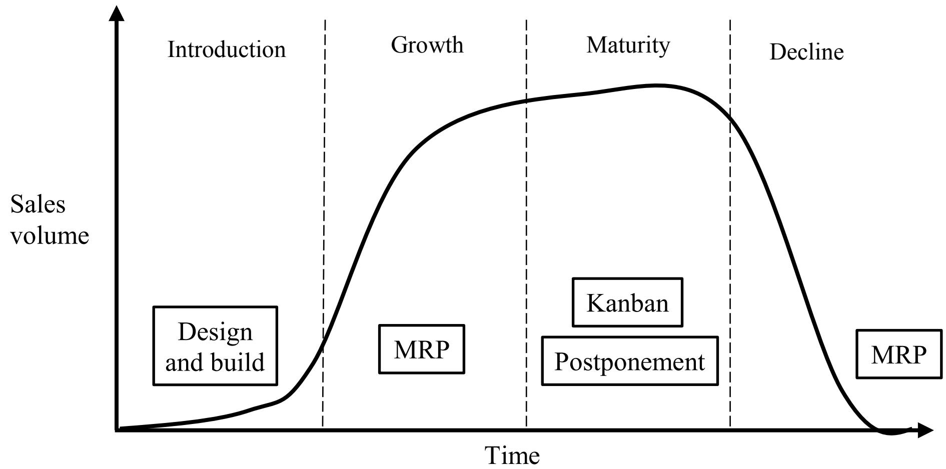


Figure 8. Supply chain strategies based on product life cycle (Aitken et al. 2003)

4 Supply chain management

This chapter first provides a general overview on supply chain management as a concept by discussing its meaning, purpose and objectives. Next, the supply chain operations reference (SCOR) model, which is a framework for supply chain management processes and practices, is introduced in section 4.2. The following sections 4.3-4.7 discuss some of the key activities in a supply chain including transportation, inventory management, distribution, reverse logistics and performance measurement. Finally in section 4.8, supply chain integration is discussed which is an important determinant for effective supply chain management and operational performance.

4.1 Defining supply chain management

Various definitions for supply chain management have been proposed after the 1980s when the concept started to receive increased attention both from practitioners and academics. The definition adopted in this research is from the Council of Logistics Management (1986). They define supply chain management (SCM) “as the process of planning, implementing, and controlling the efficient flow and storage of raw materials, in-process inventory, finished goods and related information flow from point-of-origin to point-of-consumption for the purpose of conforming to customer requirements”.

It is essential to part supply chain management from traditional logistics management since SCM extends the management activities to cover the complete supply chain rather than focusing only on logistics operations such as transportation and inventory management (Cooper et al. 1997). Houlihan (1985) has argued that the objective of SCM is to lower the amount of required resources in order to provide the desired service level for the customers. In addition, SCM synchronizes the material flows from suppliers with the requirements from the customers (Stevens 1989) and can lead to reduced inventory levels, increased customer service and competitive advantage (Cooper 1993, La Londe 1997). These in turn have effects on performance as researchers have found that higher levels of supply chain management activities are associated with higher levels of firm operational and financial performance (Li et al. 2006, Tan et al. 1999).

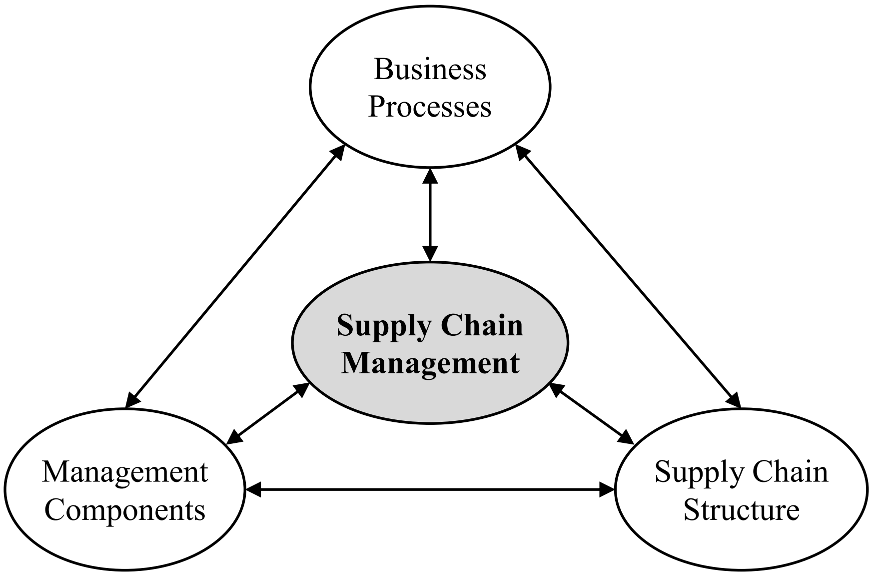
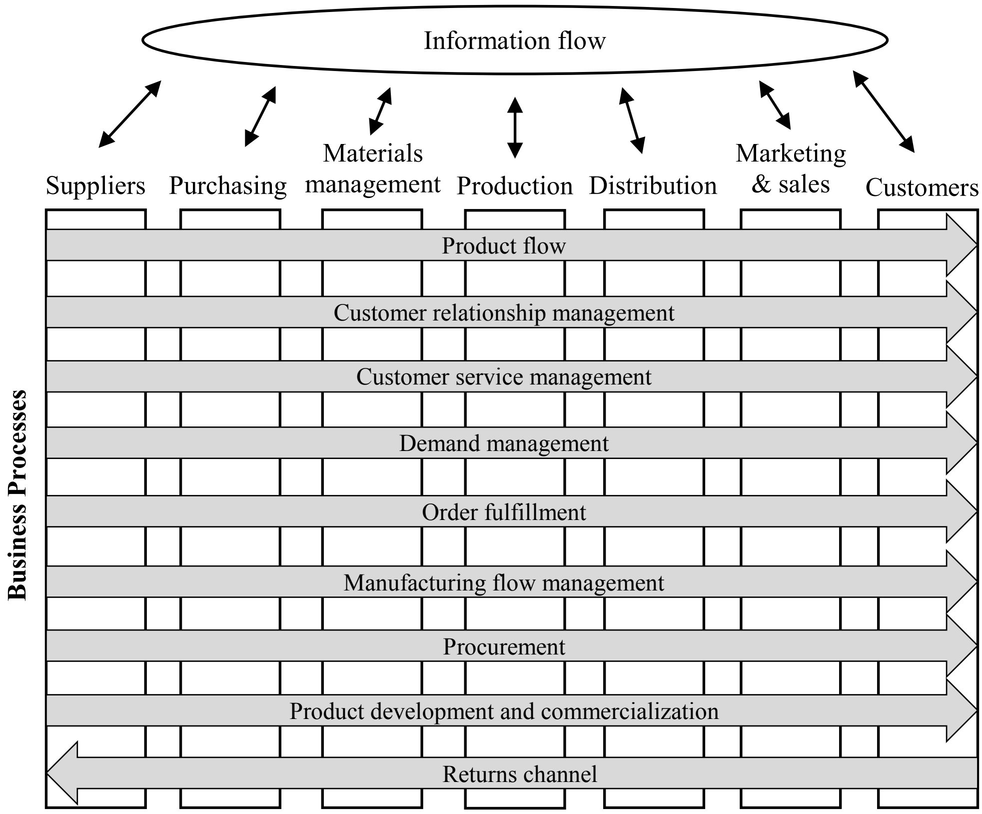


Figure 9. Major elements in supply chain management (Cooper et al. 1997)

Cooper et al. (1997) have proposed that supply chain management consists of three basic and interrelated elements: supply chain business processes, supply chain management components and supply chain structure as presented above in Figure 9. Business processes refer to the actual supply chain activities, e.g. procurement and manufacturing flow management that produce valuable outputs to the customers. Management components are the set of components by which the business processes are managed and structured. Finally the third element, supply chain structure, describes the configuration of actors and companies participating in the supply chain. (Cooper et al. 1997) Figure 10 presents a more detailed illustration of the sub-processes and activities in each of the three elements.



Management Components

- Planning and Control
- Work structure
- Organization Structure
- Product flow facility structure
- Information flow facility (IT) structure
- Product structure
- Management methods
- Power and leadership structure
- Risk and reward structure
- Culture and attitude

Figure 10. Supply chain management framework (Cooper et al. 1997)

Other authors have presented similar activities and processes in supply chain management such as customer relationship management (Li et al. 2006, Tan et al. 1999), supplier base management and ensuring long-term strategic partnerships (Li et al. 2006, Mentzer et al. 2001, Tan et al. 1999) and the importance of information sharing between actors in the supply chain (Mentzer et al. 2001). Although effective supply chain management requires efforts from all functions within an organization, Cooper & Ellram (1993) have focused specially on purchasing and logistics operations. They argue that purchasing and logistics functions can contribute to supply chain management by (1) providing leadership in the process, (2) providing inventory management expertise, (3) facilitating information links between and within firms, (4) providing negotiation expertise, (5) providing expertise in working with third parties and (6) by presenting a broad and inter-organizational perspective.

4.2 Supply chain operations reference (SCOR) model

The supply chain operations reference (SCOR) model is a business process reference model designed for cross-functional and integrated supply chain management. The model provides common definitions, processes and metrics to all actors in the supply chain including (1) standard descriptions of supply chain management processes, (2) standard performance metrics, (3) description of best practices and (4) mapping of software products for supply chain management. Using the model, companies can evaluate their own processes, benchmark their performance to others, utilize best practice information to prioritize their activities and identify software suited to their specific needs. (Stewart 1997)

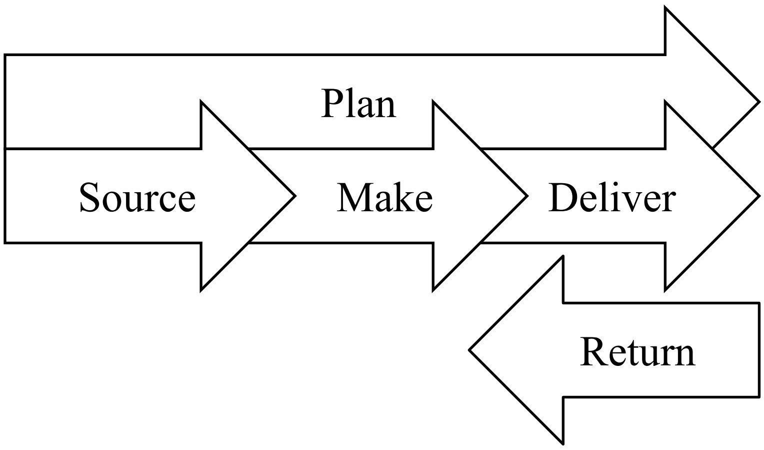


Figure 11. Supply chain operations reference (SCOR) model (Stephens 2001)

The original SCOR model included four primary components of the supply chain: plan, source, make and deliver that together cover the complete supply chain (Stewart 1997). Later, product returns from customers were added as an additional component to the model as presented above in Figure 11 (Stephens 2001). SCOR model consist of four levels of supply chain management. Level 1 defines broadly the plan, source, make, deliver and return process types. Level 2 defines 26 core process categories that companies can use to structure their supply chains. Level 3 describes the level 2 process categories in a more detailed level and provides companies the necessary information to plan and set goals for their supply chain improvements. Finally, level 4 focuses on implementation when companies actually implement their supply chain improvements. (Stewart 1997)

The next five sections, sections 4.3-4.7, are arranged following the five basic process types in the SCOR model. Transportation mode and delivery term choices covered in section 4.3 refer to the source process type by focusing on transportation mode and delivery terms alternatives when sourcing materials from global suppliers. Section 4.4 is related to the make process type and discusses asset and capacity management in terms of positioning and controlling strategic inventory in the supply chain. This is followed by discussing distribution operations in section 4.5 which is tightly related to the deliver process type. Next, related to the return process type, the concept of reverse logistics in introduced in section 4.6. Finally, section 4.7 focuses primarily on supply chain performance measurement related to the plan process type since supply chain structural decisions were already covered in chapter 3.

4.3 Transportation and delivery terms

Transportation can be typically divided into four modes: sea, rail, road and air freight (Coulter et al. 1989, Punakivi & Hinkka 2006). Sea freight is most suitable for large quantities over long distances but is limited to destinations with water and port access and thus, decreasing the mode's flexibility. In addition, sea freight is the slowest of all four modes. Rail freight, on the other hand, can be used for high-volume and weight transportation inland but this alternative is restricted by the rail network. Advantage over sea freight is the faster transportation speed. Road freight is effective for shorter distances as it can offer flexible service and responsiveness to changing customer needs. Finally, air freight is clearly the fastest mode but its disadvantages include high costs and limitations in carrying capacity. (Punakivi & Hinkka 2006)

Speed, price, reliability, accuracy, scheduling, convenience and safety are typical selection criteria for transportation mode. However, Punakivi & Hinkka (2006) have found that the importance and ranking of these criteria depends heavily on the industry in question. According to their findings, the electronics industry typically favor faster modes since products have high price/weight ratios and short product life cycles. On the other hand, in the construction industry, price is usually the most important selection criteria since operations are local and thus, transportation distances are relatively short. In addition, scheduling and punctuality are important due to the project-based nature of construction business requiring the deliveries to be at site on a given time. (Punakivi & Hinkka 2006)

In addition to selecting the transportation mode, it is important to consider the delivery terms when planning purchases and deliveries from global suppliers. International Chamber of Commerce (ICC) (2010) have defined standard delivery terms for international trade and commerce, last revision termed as Incoterms 2010. These terms define the basic obligations, costs and risks between the seller and buyer related to the delivery of goods.

Table 5. Incoterms 2010 delivery terms (International Chamber of Commerce, 2010)

Terms for any mode of transport	
EXW (Ex Works)	Seller delivers when it places the goods at the disposal of the buyer at the seller's premises or at another named place (i.e. works, factory, warehouse, etc.).
FCA (Free Carrier)	Seller delivers the goods to the carrier or another person nominated by the buyer at the seller's premises or another named place.
CPT (Carriage Paid To)	Seller delivers the goods to the carrier or another person nominated by the seller at an agreed place and that the seller must contract for and pay the costs of carriage necessary to bring the goods to the named place of destination.
CIP (Carriage And Insurance Paid to)	Same as CPT but seller also contracts for insurance cover against the buyer's risk of loss of or damage to the goods during the carriage.
DAT (Delivered At Terminal)	Seller delivers when the goods, once unloaded from the arriving means of transport, are placed at the disposal of the buyer at a named terminal at the named port or place of destination.
DAP (Delivered At Place)	Seller delivers when the goods are placed at the disposal of the buyer on the arriving means of transport ready for unloading at the named place of destination.
DDP (Delivered Duty Paid)	Seller delivers the goods when the goods are placed at the disposal of the buyer, cleared for import on the arriving means of transport ready for unloading at the named place of destination.
Terms for sea and inland waterway transport	
FAS (Free Alongside Ship)	Seller delivers when the goods are placed alongside the vessel (e.g., on a quay or a barge) nominated by the buyer at the named port of shipment.
FOB (Free on Board)	Seller delivers the goods on board the vessel nominated by the buyer at the named port of shipment or procures the goods already so delivered.
CFR (Cost and Freight)	Seller delivers the goods on board the vessel or procures the goods already so delivered.
CIF (Cost, Insurance and Freight)	Same as CFR but seller also contracts for insurance cover against the buyer's risk of loss of or damage to the goods during the carriage.

Table 5 summarizes the delivery terms defined by ICC. Terms are arranged according to the balance of obligations and risks between the seller and buyer. EXW represents the minimum obligations for the seller since the buyer handles the transportation and carries all risks from the seller's premise. On the opposite side, DDP places the maximum obligations on the seller requiring the seller to handle delivery to the buyer's named destination which includes being responsible of all costs and other formalities such as taxes and customs.

4.4 Inventory positioning and control

Strategic inventory in the form of raw materials, semi-finished or finished products can be used as a buffer in the supply chain to reduce the uncertainties related to material supply or demand (Lockamy & Draman 1998). One common method to approach strategic inventory placement is to place inventory in the ODP (Hoekstra & Romme 1992). ODP separates the forecast-driven (upstream) planning activities from the demand-driven (downstream) activities in the supply chain and acts as the main point where customer demand is supplied (Childerhouse & Towill 2000). Thus, inventory hold at ODP is to buffer between uncertainties both in demand and supply. It is also important to point out that the ODP is generally considered as the last point in the supply chain at which inventory is held (Sharman 1984).

But where the ODP and thus, strategic inventory should be placed in the supply chain? Generic production strategies in relation to the position of the ODP where already discussed in chapter 3 so the aim here is to focus only on the factors determining the position. Researchers have proposed several factors affecting the position as presented in Table 6. These factors can be divided into three categories: market, product and production/logistics system related factors (Olhager 2003, Pagh & Cooper 1998).

Pagh & Cooper (1998) argue that market related factors are perhaps the most important when determining ODP position. Delivery lead time requirements set by the customers determines the farthest point upstream where the ODP can be positioned. In addition, product demand volatility, uncertainty and customization requirements are important when considering the possibility to make products to stock (MTS) or to order (MTO). If uncertainty and customization requirements are high, is it beneficial to make products based on customer orders. However, with stable and predictable demand and limited customization requirements, forecasting is more accurate and products can be made to stock and customers supplied form the finished goods inventories. Finally, customer order size and frequency should be taken into account since frequent demand with small order sizes is best fulfilled close to the customer. (Olhager 2003, Pagh & Cooper 1998)

Table 6. Factors affecting positioning inventory and order decoupling point (ODP) (Olhager 2003, Pagh & Cooper 1998)

Market related factors	Product related factors	Production/logistics system related factors
Delivery lead time requirements Demand uncertainty/volatility Customer order size and frequency Product customization requirements	Product design Product life cycle Customization opportunities Monetary density and value profile Material profile and product structure	Production lead time Flexibility Position of bottleneck Number of planning points Special knowledge Economies of scale

Product design is one important factor including to the product related factors. For products with modular design, it is possible to position the ODP upstream in the supply chain and, at the same time, maintain product customization opportunities. However, products with standard designs are more typically stored closer to the customer i.e. downstream in the supply chain. Product life cycle determines the service level requirements in the supply chain (Pagh & Cooper 1998). Introduction and growth life cycle phases typically require high service level and thus, inventories should be placed closer to the customer. On the other hand, minimizing cost and risk is important in maturity and decline phases which indicates that inventories should be placed more upstream in the supply chain to enable economies of scale and minimize inventory risks. (Olhager 2003, Pagh & Cooper 1998)

Finally, production and logistics system factors are related to the actual capabilities of the supply chain system. Production lead time is an important factor since it poses a major constraint on the ODP position also linking to the delivery lead time requirements. Flexibility is also crucial since it enables the supply chain to respond to sudden changes and variation in demand. (Olhager 2003, Pagh & Cooper 1998) Thus, flexibility is needed when inventories are placed upstream in the supply chain. Pagh & Cooper (1998) also pointed out that economies of scale are better achieved with forecast-driven methods by producing products to stock which are located close to the customer.

Rather than just listing the factors affecting the positioning of the ODP, it should be pointed out that some of the factors are interrelated. Olhager (2003) has proposed a conceptual impact model for the factors which is presented in Figure 12. Market related factors are the starting point since the underlying purpose of all supply chains is to create value for the customers (Pagh & Cooper 1998). Market factors further affect product factors such as the requirement for high product variety. Market and product related factors together determine the delivery lead time requirements as illustrated in the figure. Market and product factors are also inputs for the production and logistics systems by setting the requirements and constraints for the systems. These together with product related factors determine the production lead time.

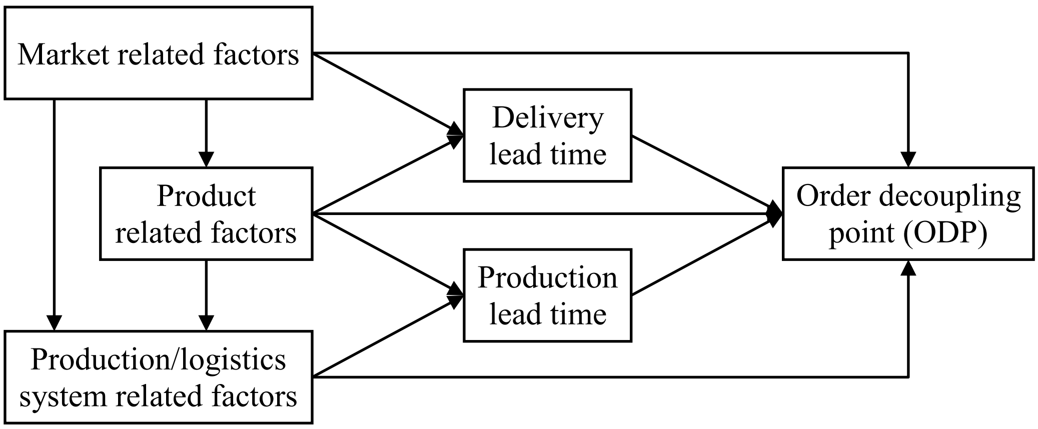


Figure 12. Conceptual impact model for factors affecting positioning of ODP (modified from Olhager 2003)

This leads to the conclusion that the relationship between delivery and production lead times becomes a major determinant of the ODP position. (Olhager 2003) As a rule of thumb, if the required delivery time is shorter than production lead time, forecast-driven operations are needed ahead of demand and ODP is positioned closer to the customer. However, if the production lead time is shorter than the required delivery time, production can be initiated later based on actual customer orders and thus, ODP is positioned more upstream in the supply chain allowing increased opportunities for product customization and the ability to reduce downstream inventories.

After discussing the positioning of strategic inventory, attention is pointed towards how to actually control the inventories once their location in the supply chain have been decided. Effective management of inventory is important since high levels of inventory have found to have a negative effect on firm financial performance (Koumanakos 2008).

The fundamental problem related to inventory control includes two decisions: when to place replenish orders and the quantity to be ordered (Wilson 1934).

Various inventory control models have been proposed to solve this challenge. Williams & Tokar (2008) have provided a comprehensive review of these models presented in the literature between the years 1976 and 2007. Their main insight is that inventory control models can be classified into two categories: traditional and collaborative inventory control models. Inventory control models presented is the past tend to integrate inventory control models with traditional internal logistics activities such as warehousing and transportation. However, more recently, researchers have proposed inventory control models that focus more on collaboration with external supply chain actors by sharing information that is essential for ensuring reliable supply of goods to the customers. Inventory control models in these two categories are presented in Table 7.

Table 7. Traditional and collaborative inventory control models (Williams & Tokar 2008)

Traditional inventory control models	• Reorder point methods (*Q, r*) • Periodic review methods (*S, T*)
Collaborative inventory control models	• Continuous replenishment planning (CRP) • Efficient customer response (ECR) • Quick response (QR) • Vendor-managed inventory (VMI)

Reorder point (*Q, r*) inventory control models focus on placing replenish orders of size *Q* when the inventory level reaches a reorder point (*r)* and economic order quantity (EOQ) is one of the oldest control models in this category (Harris 1913). As the name implies, EOQ is the replenish order quantity that minimizes total inventory holding and ordering costs. Another more simple model belonging to (*Q, r*) category, is to place orders when the inventory level reaches the reorder point and order the quantity equal to the expected demand during the replenishment lead time (Wilson 1934). Finally, the third reorder point inventory control model, base stock policy, assumes that the inventory should be maintained at the base level and replenish orders are made with the smallest possible quantities, ultimately with the quantity of one (Verma 2006). In addition to reorder point models, models based on periodic review (*S, T*) have been widely used (Williams & Tokar 2008). Originally presented by Hadley and Whitin (1963), (*S, T*) models place replenish orders through pre-defined review intervals (*T*) rather than waiting until the inventory level reaches a certain level. At the review interval, quantity is ordered such that the inventory level reaches the upper level (*S)*.

However, recently researchers have started to emphasize the importance of inter-firm collaboration and integration in the supply chain context. This also has implications for logistics as Stank et al. (2001) found that supply chain collaboration had positive effects on logistical service performance. To respond to this emphasis, researchers have started to study and propose inventory control models based on external collaboration including continuous replenishment planning (CRP), efficient customer response (ECR), quick response (QR) and vendor-managed inventory (VMI) models (Williams & Tokar 2008). What is common for all collaborative inventory control methods is that the objective is to achieve more efficient inventory control by sharing information in the supply chain (Daugherty et al. 1999).

CRP and VMI are both quite similar automatic inventory replenish models for frequent inventory replenishment with small replenish orders compared to the traditional inventory control models. The difference is that, in VMI, the supplier decides about the replenish orders i.e. order quantity and time, contrast to CRP where the focal firm makes the decisions. ECR and QR inventory replenishment models are more used in the grocery and apparel industry where demand volatility and the number of product variants are high. Thus, their goal is to ensure that products are available to customers with the lowest possible lead times. (Williams & Tokar 2008)

4.5 Distribution

Distribution considers the activities of moving and storing products from manufacturers to the final customers (Chopra 2003). Various parties are engaged in the distribution network including manufacturers, distributors, retailers and customers. In addition to the actors, the distribution network also consists of many physical assets including warehouse facilities and transportation fleets. Figure 13 presents the typical structure of a distribution network with multiple tiers of customers.

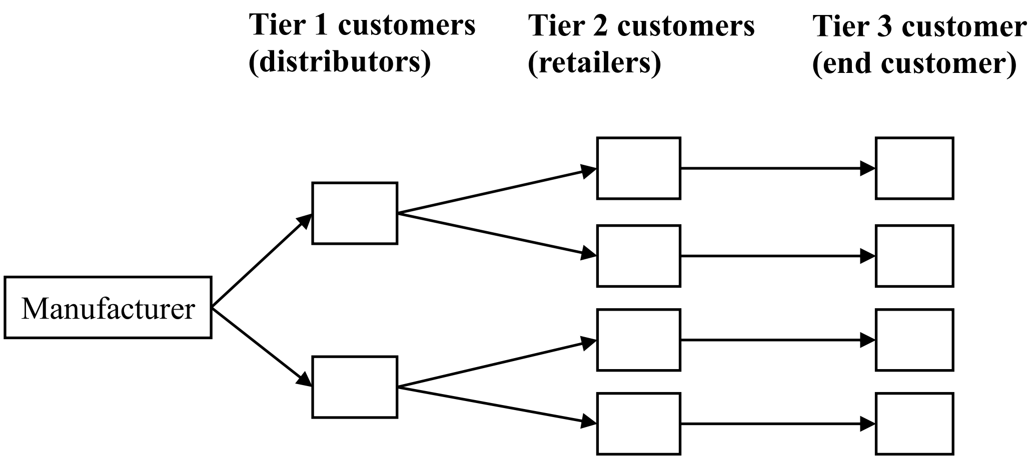


Figure 13. Generic distribution network (Cooper et al. 1998)

Chopra (2003) argues that there are two crucial decisions in distribution network design: (1) direct delivery to customer or pick-up from a pre-defined place and (2) intermediate routing location for material flows or not. Based on these two decisions, six different distribution network design are identified depending on material flows and warehousing locations:

- Manufacturer warehouse with direct shipping
- Manufacturer warehouse with direct shipping and in-transit merge
- Distributor warehouse with package carrier delivery
- Distributor warehouse with last mile delivery
- Manufacturer/distributor warehouse with customer pick-up
- Retail warehouse with customer pick-up (Chopra 2003)

In the first option, products are shipped directly to the customer from the manufacturer. The major benefit of this design is that it enables centralized warehousing and the ability to aggregate demand and to provide higher product availability with lower inventories compared to distributors and retailers. However, transportation costs in this approach tend to be higher due to the average outbound transportation distance being higher compared to local warehouses of distributors and retailers. In addition, full truckload (FTL) deliveries are not an option since products are delivered directly to customers more frequently and in smaller quantities based on received orders. Manufacturing warehouse with direct shipping and in-transit merge differs from the previous design by merging deliveries in one location (e.g. cross-dock terminal) allowing a single delivery to the customer rather than multiple deliveries from different factories. Major benefit is that this method allows to use FTL deliveries to the merge location decreasing transportation costs. (Chopra 2003)

The next two designs, distributor warehouse with package carrier or last mile delivery, focus on holding inventory at the distributor. In distributor warehouse with package carrier delivery design, products are delivered to customers from a few distribution centres using package carriers. This design requires less investments in the facilities, decreases warehousing costs but, on the other hand, increases the distribution costs due to using package carries over longer transportation distances. The other design, distributor warehouse with last mile delivery, focuses on keeping inventory in many distribution centres and making final deliveries with short-distance last mile deliveries resulting in decreased lead times and improved service level. However, the facility costs are significantly higher since more warehousing locations are required. (Chopra 2003)

The last two designs involve keeping inventory at the manufacturer, distributor or retailer and allowing customer to pick up their orders from pre-defined locations. Retailer warehouse with customer pick-up allows high service level and short response times due to the local warehouses but, at the same time, increases inventory holding costs due to high number of inventory locations. Major advantage is decreased outbound transportation costs since customer is responsible for the pick-up. Manufacturer/distributor warehouse with customer pick-up design lowers the inventory holding costs due to the lower number of warehousing locations. However, customer service level is decreased due to fewer options in pick-up location and increased distances for the customer. (Olhager 2003) Performance characteristics for all of the designs are presented in Table 8.

Table 8. Performance characteristic of six distribution network designs (Chopra 2003)

Performance factor	Manufacturer warehouse with direct delivery	Manufacturer warehouse with in-transit merge	Distributor warehouse with package carrier delivery	Distributor warehouse with last mile delivery	Manufacturer /distributor warehouse with customer pick-up	Retail warehouse with customer pick-up
Inventory cost	Low	Low	Low to medium	Medium	Low	High
Transportation cost	Medium to high	Medium	Low to medium	High	Low	Low
Facilities and handling cost	Low	Low to medium	Medium	Medium to high	Medium	High
Response time	Medium to high	Medium to low	Medium	Medium	Medium	Low
Product availability	High	High	Medium to high	Medium	High	Medium

The choice between manufacturer, distributor or retailer warehousing is strongly linked to the degree of postponement in the supply chain. Manufacturing postponement was already discussed in chapter 3 but postponement is also possible regarding logistics and distribution activities. The idea in logistics postponement is to maintain inventory in one or a couple of strategic locations upstream in the supply chain (Bucklin 1965). In other words, changes in the inventory location towards downstream supply chain are postponed to the last possible point (Pagh & Cooper 1998). In contrast to postponement, logistics speculation aims to move products to forward inventories as early as possible to reduce the supply chain costs (Bucklin 1965). Thus, logistics speculation based on forecasts enables economies of scale in logistics operations by using large transportation lot sizes (Pagh & Cooper 1998).

Based on the degree of postponement, two logistics and distribution strategies emerge: logistics speculation and logistics postponement as presented in Figure 14 (Pagh & Cooper 1998). In the logistics speculation strategy, logistics operations are executed according to forecasts by stocking products close to the customer. Thus, the distribution network is decentralized with local distribution centers and warehouses. The strategy enables high service level towards customers and provides economies of scale when transporting goods to the decentralized warehouses in large lots. However, inventory costs are high due to many inventory locations and inventory risks in terms of stock outs and excess inventory are more probable (Pagh & Cooper 1998).

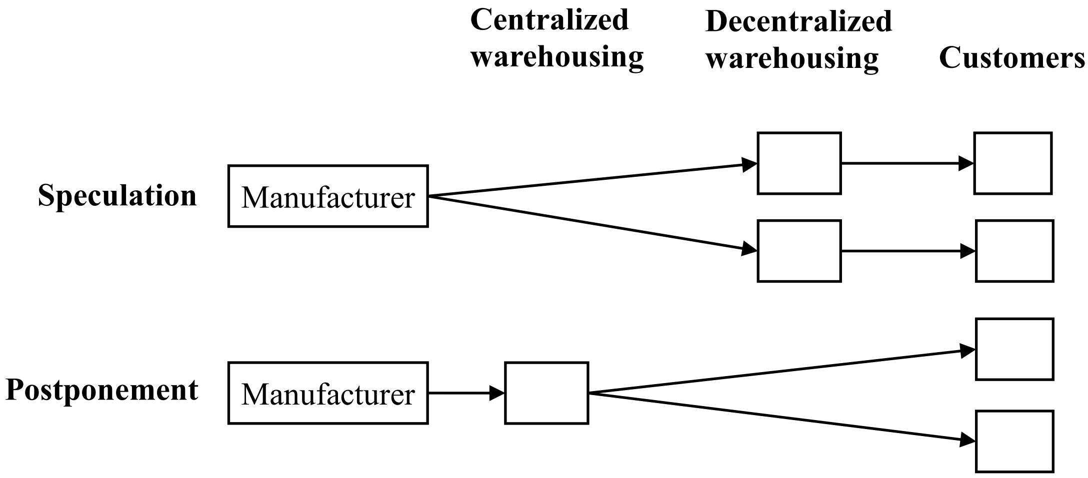


Figure 14. Logistics speculation and postponement strategies (adopted from Pagh & Cooper 1998)

Logistic postponement strategy, on the other hand, operates in a demand-driven mode as products are distributed to customers directly from centralized warehouses or production facilities based on actual customer orders. This approach reduces inventory handling costs since inventory is held at a single location. In addition, inventory control is simpler and less facility investments are required. However, transportation costs are higher compared to the decentralized strategy since orders are shipped more frequently in smaller quantities and typically with faster, more expensive transportation modes. (Pagh & Cooper 1998)

4.6 Reverse logistics

Stock (1998) has defined reverse logistics as "the role of logistics in product returns, source reduction, recycling, materials substitution, reuse of materials, waste disposal and refurbishing, repair, and remanufacturing". In other words, if traditional logistics is concerned of material flows from manufacturer to customers, reverse logistics focuses on moving materials back from customers up until to the raw material suppliers. Thus, one important purpose of reserve logistics is to reduce the supply chain's impact on the environment and allow cost savings since materials can be reused (Rogers & Tibben-Lembke 2001).

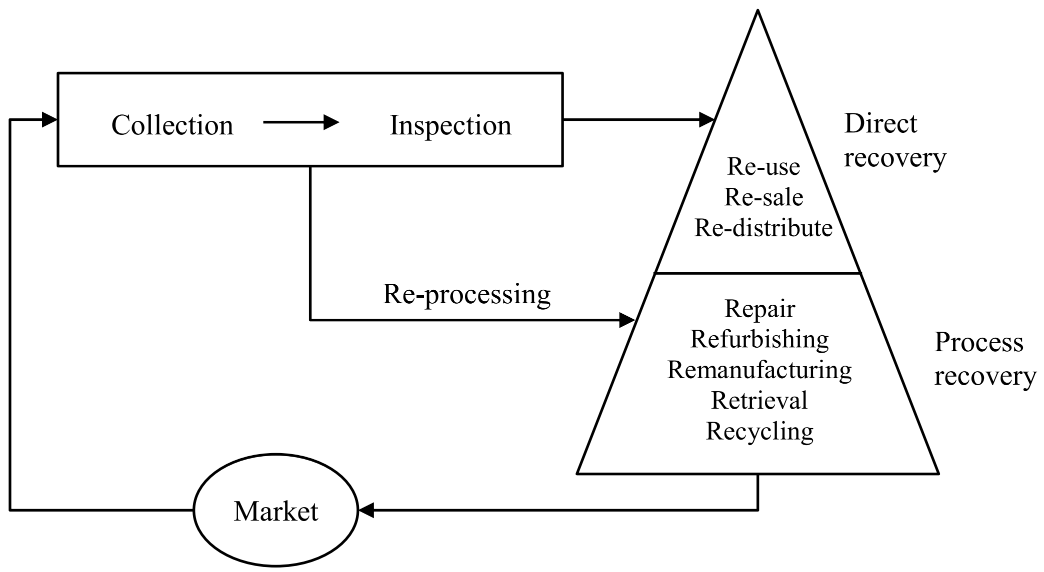


Figure 15. Reverse logistics process (De Brito & Dekker 2004)

Reverse logistics process is presented above in Figure 15. The process starts in the market where products and materials are collected in order for them to be recovered. After collection, products and materials are inspected and sorted for recovery in two alternative recovery types, direct or process recovery, based on their condition. The product quality assessed in the inspection phase determines the appropriate recovery type. If products have high quality or, in other words, their quality is "as-good-as-new", it is possible to place them very quickly back to the market through re-use, re-sale and re-distribution activities. However, if the quality is not high, re-processing activities are needed. After the recovery, materials are redistributed back to the market. (De Brito & Dekker 2004)

As it is visible in the figure, there are several activities for process recovery depending on the level: product level (repair), module level (refurbishing), component level (remanufacturing), selective part level (retrieval) and material level (recycling). Refurbishing in the component level is typical with complex products and solutions e.g. large installations and buildings when one part of the complete solution is upgraded i.e. refurbished. In component and selective part recovery levels, products are disassembled and new products remanufactured partly from old recovered components. Material recycling refers to the extraction and recycling of materials from old products in order to use the recovered materials as raw materials to manufacture new products. Finally, if the other process recovery alternatives are not possible due to very low product quality, the products can be incinerated to capture the energy or, in the worst case, sent to landfill. (De Brito & Dekker 2004)

4.7 Performance measurement

Several authors have addressed the importance of measuring performance in the supply chain environment and proposed several concrete metrics that can be used (Beamon 1999, Gunasekaran et al. 2001, Stewart 1995). This chapter discusses supply chain performance measurement first by motivating its importance which is followed by reviewing the most common measurement systems and metrics identified in the literature. Finally, practical guidelines for designing supply chain performance measurement systems and choosing appropriate metrics are presented.

Performance measurement in the supply chain is important since it provides a clear direction for improvement and enables the setting of targets. In addition, different strategies and improvements can be tested and evaluated using performance metrics. (Gunasekaran et al. 2001) It has also been argued that a performance management system is crucial for managing a business and provides vital information for decision-making and actions (Gunasekaran et al. 2007). Finally, supply chain performance measurement is essential for supply chain integration and effective management of a supply chain (Gunasekaran et al. 2001, Lai et al. 2002) and it is also argued that performance measurement increases supply chain understanding leading to improved overall performance (Shepherd & Günter 2006).

Various supply chain performance measurement systems and metrics have been presented and thus, a categorization is required. In their comprehensive literature review, Gunasekaran & Kobu (2007) identified seven categories of performance measurement in a supply chain. These include classifying systems and metrics based on: (1) measure components, (2) measure location in supply chain, (3) decision-making levels, (4) nature of measures, (5) measurement base, (6) traditional vs. modern measures and (7) balanced scorecard perspective. Table 9 below summarizes these categories.

Table 9. Categorization of supply chain performance measurement (modified from Gunasekaran & Kobu 2007)

Category criteria	Details
Measure components	• Resources/assets • Output • Flexibility/responsiveness
Location in supply chain	• Planning • Supply & suppliers • Production • Delivery • Customer
Decision-making levels	• Strategic • Tactical • Operational
Nature of measures	• Financial • Non-financial
Measurement base	• Quantitative • Qualitative
Traditional vs. modern measures	• Function-based • Value-based
Balanced scorecard perspective	• Financial • Internal process • Customers • Innovation and learning

Beamon (1999) proposed that supply chain performance measurement systems can be divided into three components: resources, output and flexibility. Resources include inventory levels, personnel and production capacity, and the goal is to achieve high utilization of these resources. Distribution costs, inventory costs and return on investment (ROI) are examples of supply chain resource metrics. Output relates to customers and supply chain's capability in providing these outputs. Order lead times, customer satisfaction and product quality can be seen as output supply chain metrics. Finally the third component, flexibility, refers to the supply chain's ability to respond to volume and schedule changes from both suppliers and customers. Beamon (1999) Other researchers have also proposed component-based performance systems. Neely et al. (1995) have found that metrics can be classified based on time, quality, flexibility and cost, and Stewart (1996) emphasize delivery performance, flexibility and responsiveness, logistics costs and asset management as components. Delivery performance, flexibility and responsiveness are custom-facing metrics concerned how well the supply chain delivers products to customers. Logistics costs and assets, on the other hand, are internal-facing metrics and focus on the efficient operation of the supply chain. (Lai et al. 2002)

Location in the supply chain is another approach for performance measurement including phases of plan, source, make, deliver and customer following the process types in the SCOR model (Gunasekaran et al. 2001, Lockamy & McCormack 2004). Plan phase involves activities such as forecasting and planning for future demand, and considerations of matching demand and supply. Forecasting error and order lead time can be used as performance metrics in the plan phase. Source phase is related to the company's supply side and supplier base. Common metrics are supply lead times, quality and price levels. Make phase is concerned about the actual production activities including capacity utilization and effectiveness of scheduling techniques as performance metrics. Deliver and customer phases are linked to the customer interface when finished goods are delivered to the customer. Typical metrics include order fill lead time, total distribution costs, flexibility to meet particular customer needs and customer satisfaction. (Gunasekaran et al. 2001) Comprehensive set of performance metrics linked with SCOR model supply chain phases are presented in Figure 16.

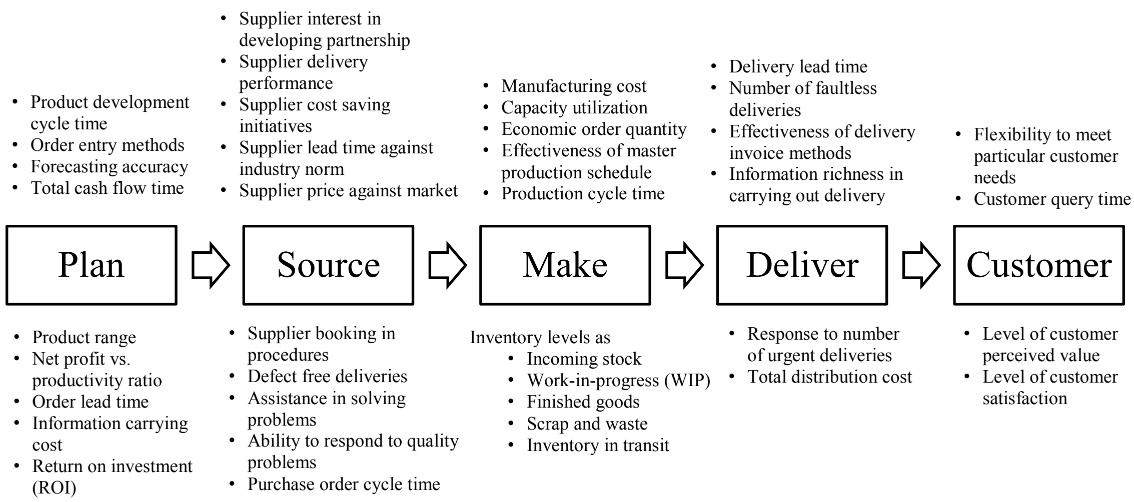


Figure 16. SCOR phases and performance metrics (Gunasekaran et al. 2001)

Performance metrics can also be classified to as financial or non-financial. Advantages of financial metrics are that they are quite easily obtained and measured due to their quantitative nature. Financial metrics include for example the total supply chain costs and ROI. However, the problem with financial metrics is that they are often obtained quite late due to financial reporting systems in organizations and thus, are suitable for strategic decisions and external reporting but not measuring real time operational performance of the supply chain. However, non-financial metrics are more appropriate in the operational level. Non-financial metrics can be both quantitative and qualitative such as lead times and product quality levels. Challenge with qualitative metrics is that they might be hard to quantify and measure in practice. In addition to these classifications, metrics can also be divided based on the decision-making level being strategic, tactical or operational. (Gunasekaran et al. 2001)

The importance of using balanced performance management systems has also been emphasized in the supply chain context (Stewart 1995). The balanced scorecard (BSC) introduced by Kaplan & Norton (1992) has become a popular tool to address this problem. The objective of the scorecard is to provide a balance between financial and non-financial metrics across short, mid and long-term time horizons. BSC should adopt performance metrics from four different areas: financial, internal processes, customer, and innovation and learning (Kaplan & Norton 1992). As the name suggests, financial perspective relates to the organization's financial performance in a strategical and long-term level including metrics such as profit margins and ROI. Internal processes perspective is concerned of internal process efficiency and capability to satisfy customer needs. Customer perspective is directly related to customers by capturing their opinions including customer satisfaction as a metric. Finally, innovation and learning perspective is related to the continuous improvement of the supply chain and how to ensure satisfied customers also in the future. (Brewer and Speh 2000). Table 10 illustrates supply chain goals and related metrics for each of the four perspectives in the balanced scorecard.

Table 10. Supply chain balanced scorecard framework (Brewer and Speh 2000)

Perspective	Goals	Measures
Financial	Profit margins	Profit margin by supply chain partner
	Cash flow	Cash-to-cash cycle
	Revenue growth	Customer growth and profitability
	Return on assets	Return on supply chain assets
Internal processes	Waste reduction	Supply chain cost of ownership
	Time compression	Supply chain cycle efficiency
	Flexible response	Product variety/average response time
	Unit cost reduction	% of supply chain target costs achieved
Customer	Customer view of product	Number of customer contact points
	Customer view of timeliness	Relative customer order response time
	Customer view of flexibility	Customer perception of flexibility
	Customer value	Customer value ratio
Innovation and learning	Product/process innovation	Product finalization point
	Partnership management	Product category commitment ratio
	Information flows	Number of share data sets/total data sets
	Threats and substitutes	Performance of competing technologies

As can be seen from the discussion above, large number of performance metrics have been introduced and this makes it difficult to select the appropriate ones in a specific supply chain context and thus, one of the most challenging areas that organizations are facing is to develop supply chain performance measurement systems (Beamon 1999). The starting point of any performance measurement system is that the selected measures must be linked to the supply chain goals and organization's strategy (Beamon 1999, Brewer and Speh 2000, Gunasekaran et al. 2001, Shepherd & Günter 2006). Thus, each organization requires a unique set of performance measures in their supply chain (Kaplan & Norton 1992).

Another important factor when designing performance measurement systems is to select metrics that capture the performance of the entire supply chain. One of the most common problems in performance measurement is that companies only use metrics related to internal logistics performance which does not measure the complete supply chain (Lee &

Billington 1992, Shepherd 2006) Thus, single performance metrics are generally not enough to capture the supply chain as a whole (Beamon 1999).

Designing a supply chain performance measurement system can be started by identifying the key processes and activities to be measured, selecting appropriate levels of management where the metric should be applied and finally, selecting the metrics themselves. It is often also beneficial to appoint each metric to a responsible person who regularly follows the metric and takes corrective action if necessary (Gunasekaran et al. 2004) In addition, the selected metrics should be quantifiable, easy to understand and ones that allow cost-effective data collection and analysis (Bhagwat & Sharma 2007).

4.8 Supply chain integration

Supply chain integration is defined as “the degree to which a firm strategically collaborates with its supply chain partners and collaboratively manages intra- and inter-organization processes” (Flynn et al. 2010 p. 59). Integration is important since information sharing and collaboration focuses more resources, both human and financial, on business operations enabling more informed decisions and risk reduction (Stank et al. 2001). In addition, many researchers have found the positive effect of integration on supply chain performance (e.g. Flynn et al. 2010, Frohlich & Westbrook 2001, Prajogo & Olhager 2012).

Different strategies and approaches for supply chain integration are typically classified based on the degree and direction of integration. Regarding the direction, in addition to internal integration, a firm can integrate externally upstream towards suppliers and downstream towards customers (Flynn et al. 2010, Frohlich & Westbrook 2001). Thus, firms can choose between four high-level integration strategies: internal integration, customer integration, supplier integration and complete integration towards both suppliers and customers (Fawcett & Magnan (2002). The degree of integration is related to external integration since a firm can choose to integrate only with its first-tier suppliers and customers, or also include lower-tier suppliers and customers in collaboration and information sharing (Fawcett & Magnan 2002). Based on these considerations, Fawcett & Magnan (2002) have presented five supply chain integration strategies depending on the degree and direction of integration as illustrated in Figure 17.

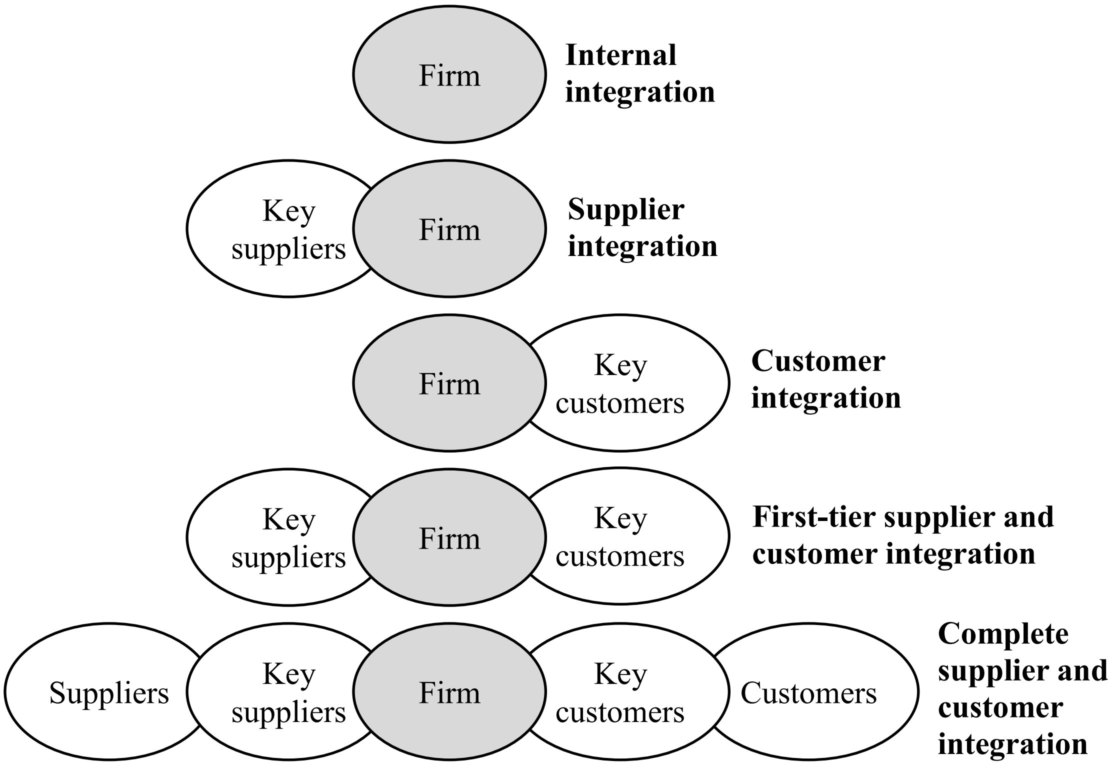


Figure 17. Supply chain integration strategies (modified from Fawcett & Magnan (2002))

An important starting point in supply chain integration is to establish internal integration within the firm by increasing collaboration and information sharing between different functions such as R&D, purchasing, production, marketing and logistics within an organization since internal integration is the foundation for customer and supplier integration (Flynn et al. 2010). After internal integration, collaboration with suppliers and customers can be increased. Common supplier integration practices are related to purchasing and inbound material flow management including for example Just-In-Time (JIT) and collaborative inventory control models (Frohlich & Westbrook 2001). On the other hand, customer integration deals with the customer interface mainly taking into account the customer requirements and needs in the supply chain (Frohlich & Westbrook 2001).

In addition to the degree and direction, integration can also be described based on its nature being either information or material flow integration as presented in Figure 18 (Frohlich & Westbrook 2001, Prajogo & Olhager 2012). Material flow integration is related to the forward flow of materials from suppliers to customers focusing heavily on integrating logistics and distribution processes. Information integration, on the other hand, considers the backward flow on information from customers to suppliers for example by using electronic data interface (EDI) technologies and point-of-sales data in supply chain planning. (Prajogo & Olhager 2012)

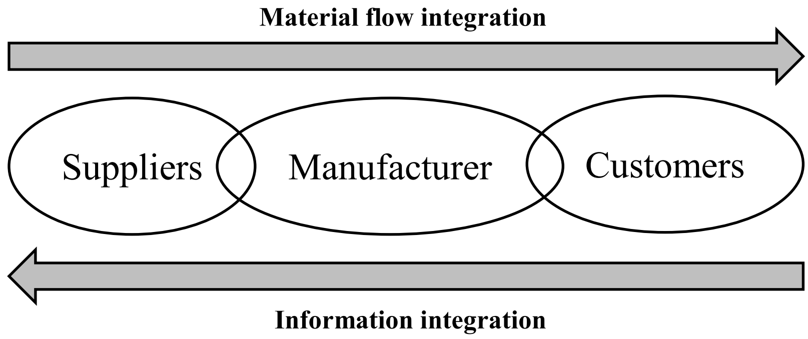


Figure 18. Material flow and information integration

Several authors have investigated the effect of supply chain integration on supply chain performance. Stank et al. (2001) focused on logistics performance and found that internal integration has a significant positive effect on performance. However, no direct link between external integration and logistics performance was found but Stank et al. argued that external integration increases also the internal integration which in turn improves logistical service performance. Thus, it was proposed that by enhancing internal integration firms can improve logistics service performance through collaboration with external customers and suppliers (Stank et al. 2001).

Furthermore, Flynn et al. (2010) found that higher levels of supply chain integration were associated with higher levels of both operational and business performance. In addition, it was revealed that customer and internal integration had larger impact on performance than supplier integration. Prajogo & Olhager (2012) argued that information integration in terms of information technology capabilities and information sharing have significant effect on logistics integration. Logistics integration further leads to higher operations performance. Finally, Frohlich & Westbrook (2001) have found that the highest level of supply chain integration, extending both towards suppliers and customers, had the highest positive impact on supply chain performance and, on the other hand, lowest when a firm focuses only on internal integration.

5 Literature synthesis

This chapter provides a synthesis of the literature review. Aim of the synthesis is to provide a theoretical foundation for the empirical study and guidance for the solution design by providing the basic elements that should be taken into account in designing and managing a supply chain. This is visualized with a flow chart in Figure 19 including the fundamental steps and decisions relating to supply chain design such as selecting supply chain and logistics strategies, and establishing processes for supply chain management.

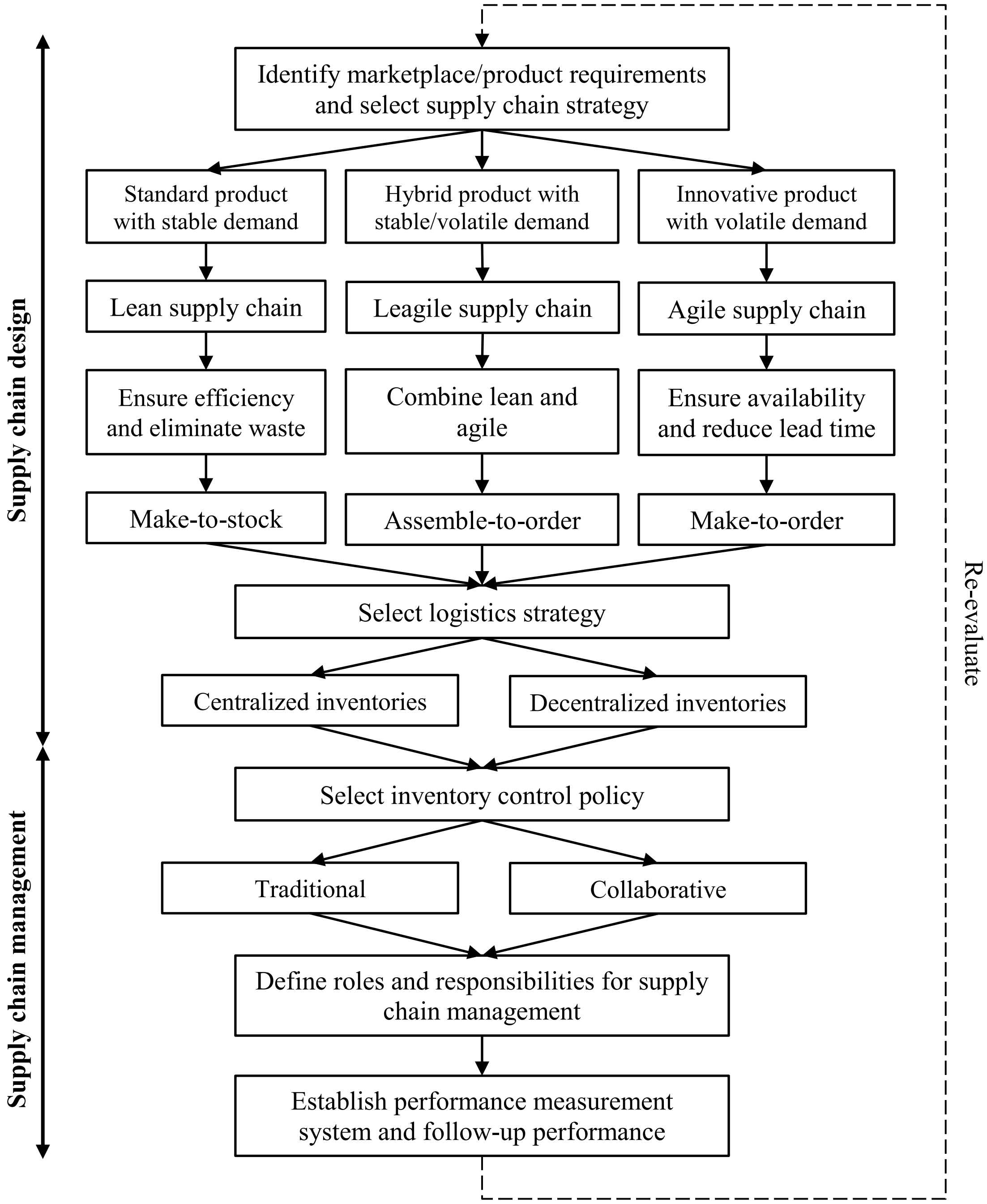


Figure 19. Flow chart for supply chain design and management

The process of designing a supply chain starts by analyzing the firm's operating environment with the aim of identifying specific marketplace and product-related requirements that have effects on the supply chain including for example demand variability, required customer service levels and supply lead times. This is an important first step since several authors have emphasized the importance of linking the supply chain strategy and type to the firm's context. It was also found out that the firm context is associated strongly with the supplied product type and that there are typically three type of products: standard, innovative or, a combination of these, hybrid product. Standard products have stable and predictable demand and thus, lean supply chain should be used with the focus in efficiency by eliminating non-value adding activities, waste, in the chain. Predictable demand also enables the use of make-to-stock production strategy with level schedules since operations can be reliably planned based on forecasts.

Innovative products are best matched with an agile supply chain since innovative products have volatile and unpredictable demand. Thus, lead time reduction and product availability are the major focus areas in the agile supply chain. Because of the unpredictable demand and high product variety requirements, make-to-order production strategy is the best option to achieve flexibility in responding to changes both in volume and mix. Finally, hybrid supply chain is best used with modular products, combination of functional and innovative components, that can be assembled and delivered based on customer orders. Thus, a hybrid supply chain combines lean and agile processes with the order decoupling point (ODP) by utilizing lean processes upstream and agile processes downstream from the ODP.

After deciding on the supply chain and production strategies, logistics processes and the actual supply chain structure should be considered. Especially important for non-manufacturing firms is the concept of logistics postponement since the degree of postponement ultimately determines the supply chain structure. Thus, the number and location of warehouse facilities and distribution channel choices are affected if the firm decides to either speculate or postpone its logistics activities. In logistics speculation, customers are supplied from decentralized warehouses which are replenished based on demand forecasts. On the other hand, logistics postponement warehouses products centrally by postponing the final distribution and delivery until the actual customer order has been received.

Next, methods for inventory control should be decided. An option is to use traditional inventory control methods such as reorder point approaches that focus more on the firm's internal activities. However, collaborative methods focusing on external collaboration and information sharing are also an option and might be more suitable in an uncertain market environment requiring high degree of supply chain integration with suppliers and customers.

It is also important to define the required processes, roles and responsibilities for supply chain management in order to effectively manage efforts and material flows in the supply chain. In addition, supply chain integration should be considered including the supporting information systems and level of collaboration with external actors. Finally, a supply chain performance measurement system should be implemented and the performance followed allowing continuous improvement of the supply chain operations. The chart also includes a re-evaluation loop from the bottom back to the top. This is important since the supply chain environment is not static and thus, requiring constant monitoring and evaluation. In some cases, the process might have to be started again if the market environment changes significantly and thus, another supply chain strategy and type are required. In addition, the product type might change according to the product life cycle phase requiring a different supply chain strategy to be used when the product moves through different life cycle phases.

Part II - Empirical study

This section presents the empirical part of the study, which was conducted as a case study in Finnish energy utility company. Research methods for the empirical study, and their reliability and validity are first discussed in the next chapter. This is followed by presenting the actual empirical findings in chapter 7, which is further divided into three subchapters covering the current situation at the case company in chapter 7.1, solution objectives and solution development in chapter 7.2 and finally, evaluation of the proposed solution in chapter 7.3.

6 Research method for empirical study

This chapter discusses the research methods used in the empirical part of the study. First, the problem-solving oriented research approach, design science, utilized in the study is introduced and described. This is followed by outlining the research process including the methods for data collection and analysis. The chapter ends by discussing the steps taken in order to ensure the reliability and validity of the research.

6.1 Design science

Design science is a research approach with the aim of solving managerially relevant and practical problems through an iterative and systematic problem-solving process (Holmström et al. 2009). The approach is similar to other practical problem-solving research approaches such as the constructive approach, action science or research, and action innovation research. What is in the centre of design science, is the development of an artifact that will solve a managerially relevant problem. In addition, design science emphasizes that the researcher is an active participant in the problem-solving process and solutions are development in cooperation with the organization rather than just observing the phenomena and forming or testing theory based on the observations. (Holmström et al. 2009)

Design science can be described as a process of exploration through design and its objectives include (1) exploring new alternatives to solve problems, (2) explaining this explorative problem-solving process and (3) improving the problem-solving process itself (Simon 1973, Holmström et al. 2009). Design science differs from explanatory research which aims to build theory using induction or test theory using deductive methods based on phenomena that already exist. Thus, design science can be viewed as exploratory research which focuses on creating the phenomena under study throughout the research process. (Holmström et al. 2009)

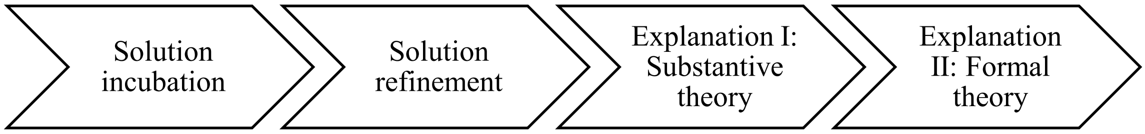


Figure 20. Generic design science research process (Holmström et al. 2009)

The generic research process for design science is presented above in Figure 20. The process starts with solution incubation where an understanding of the problem is formed after which the problem is clearly defined and framed. In addition, the foundation for the potential solution is created and its objectives set at this phase. In the next phase, solution refinement, the solution is implemented in an empirical environment and tested. It is emphasized that the process is iterative and thus, solution can be developed further after initial testing. The last two phases, explanation I and II, are linked to generalizing the findings and demonstrating the theoretical contribution of the solution. Explanation I phase is focused in establishing the theoretical relevance of the solution design. Theory developed in this phase is seen substantive theory, which is limited to the empirical context under study. Explanation II, on the other hand, aims to establish formal theory that is not linked to the specific empirical setting and thus, can be applied in other fields.

6.2 Research process

The research process for the thesis is presented below in Figure 21. It was started with a comprehensive literature review in the areas of supply chain design and configuration, and supply chain management. Aims of the literature review were to gain a deeper understanding about the research topic and study what the existing research has examined including finding potential knowledge gaps in prior research. In addition, the literature review formed the foundation and provided initial ideas for the solution design.

Figure 21. Research process for the study

Case study method was used in the empirical part of the study. Data collection was started with interviews conducted during May and June 2017 at the case company's headquarters. Interviewees were selected with purposive sampling by identifying key personnel working with consumer product offering such as product managers, business development managers and purchasing managers. More detailed description of the interview schedule and topics discussed in the interviews can be found in Appendix A. Interviews were conducted in a semi-structured manner with open-ended questions using an interview structure presented in Appendix B. All interviews were recorded and later transcribed to allow systematic data collection. The goal of the interviews was to gain more understanding about the case company's current supply chain operations and also to determine the objectives and requirements for the solution. In addition to interviews, the researcher participated in various internal meetings, discussions and workshops during the research process taking notes and making observations. Additional internal company material was identified in the interviews and discussions such as product strategies and roadmaps, purchasing contracts, market and customer research reports.

Data analysis was started by reviewing the interview transcripts. Based on this review, key pieces of information from each consumer product was divided under four categories: (1) market and customers, (2) supplier base, (3) material flows and logistics, and (4) installation services. This enabled structuring the information into a more systematic format and identifying key supply chain elements and activities for each consumer product. In addition, the category division allowed cross-product comparisons for each category in order to examine the key similarities and differences between the products in the offering. In addition to data in text format, numerical data was also tabulated whenever possible including for example product and logistics costs, sales volumes and demand forecasts. Finally, supply chain structures (including material and information flows) for each product and the complete supply network for the product offering were mapped into graphs in order to visualize and analyze the supply chain activities.

After analyzing the findings from the literature review and interviews, design of the initial solution was started in cooperation with the case company. Once the initial solution was ready, it was further developed together with the case company's thesis instructor and other key members in the consumer products area. It must be emphasized that the solution development was an iterative process since there were several times when the researcher had to review more literature or collect more empirical data based on feedback and improvement suggestions received for the solution proposal.

When the solution was developed to an appropriate level, it was presented and evaluated in three sessions attended by key managers and decision makers related to the consumer product offering such as product managers and their team leaders. Feedback, comments and improvement ideas were collected in these sessions, which allowed the proposed solution to be developed further. In addition, key employees with special expertise related to logistics and supply chain management were used to evaluate the proposed solution and suggest improvements. This kind of solution evaluation is seen as weak market testing where individual managers accept the solution to be used in their work and decision making without concrete evidence of its financial performance (Kasanen et al. 1993).

Finally in the last phase of the research process, contributions of the research were examined. This includes only covering the substantive theory related to explanation I phase, which was introduced in the previous chapter. Thus, generalization and theoretical contributions are only discussed in the context of this research since moving to the explanation II phase would require extensive research on different industries and supply chain contexts (Holmström et al. 2009).

6.3 Reliability and validity

The credibility of any research is evaluated using the concepts of reliability and validity. Results of a study are reliable if another researcher is able to achieve the same results by following the same procedures and research methods as the original researcher. Validity refers to the whole research process and examines the applicability of the chosen research methods to study the phenomena. Results are valid if they have been obtained using appropriate scientific research methods and measures. Since this thesis uses the case study research method, emphasis should be on the methods and practices to enhance case study reliability and validity. Yin (1994) have presented four areas that can be used to assess case study quality, which are internal validity, external validity, construct validity and reliability.

Internal validity refers to the internal factors of the studied problem and ensuring that causal relationships between the studied phenomena truly exist. External validity, on the other hand, is related to linking the results outside of the studied area and examines if the results can be generalized to a wider context. Third aspect of validity, construct validity, is related choosing the correct operational measures and ensuring that they actually measure the studied phenomena or variable. Construct validity can be ensured by using multiple evidence sources, linking evidence into a chain and have informants to review the case study. Finally, reliability can be verified by using case study protocol, a set of procedures, guidelines and rules to govern the research process, and by storing and organizing the data in one place forming a case study database. (Yin 1994)

Construct validity in the thesis was ensured by using all three practices discussed above. Multiple sources of evidence was used since the interviewees were from different responsibility areas, such as purchasing, business development and product management. In addition, others sources of information were used including company documents, presentations and numerical data identified in the interviews. Evidence was linked together by following the planned research process and establishing links within the evidence. Drafts of the case study report were also presented to the case company's thesis instructor in the late phases of the research.

Reliability was established with a case study protocol which included planning the interviews in advance and using an interview structure with pre-defined themes and questions. In addition, all interviews were recorded and transcribes in order to allow systematic data collection and to form a case study database for the study.

7 Empirical findings

This section discusses the empirical findings based on the case study conducted in a Finnish energy utility company. First, the current situation of the consumer product offering and supply chain operations at the case company is discussed in chapter 7.1. Next, the solution to case company problem is designed and developed in chapter 7.2 and finally its applicability evaluated in chapter 7.3.

7.1 Current situation at case company

This sections discusses the current situation at the case company related to the consumer product offering and supply chain operations. First, a brief case context description is provided which discusses the background and case company problem in a more detailed level. In the next two sections, market and customer requirements, and product types are discussed which where both identified important for supply chain design in the literature review. Finally, supply chain operations and related challenges currently at the case company are discussed.

7.1.1 Case context

As already mentioned, electricity, district heating and cooling have been the traditional core offering of the company in the past. However in the recent years, the company has started to develop and offer tangible consumer products as part of its consumer product portfolio including solar systems, electric vehicle (EV) chargers, batteries, smart home products, and solutions for controlling and managing heating. All these products are sourced from global suppliers since they are already available in the market and thus, it is not reasonable to have own manufacturing activities. A major driver behind these new product introductions is the changing nature of the energy market and thus, being able to provide solutions for energy efficiency and optimization for consumer customers.

Since the case company's traditional core competence includes producing and selling intangible products, such as electricity and heating, through power lines and pipelines, competence and experience of managing tangible material flows to consumers are not developed especially at the operational level. In addition, products in the consumer product portfolio have been introduced gradually in different countries during the last five years each having their own supply chains. As a result, various supply chain models are present and thus, the entire supply chain network is complex. Additional key factor in the case company's situation is that all products require an electrical installation at customer's house performed by a certified electrician. In addition to managing material suppliers and logistics service providers, also the installation service providers need to be managed in order to provide high quality service for the customers. Thus, a more systematic and company-wide supply chain and management processes are needed to cope with increased sales volumes in the future, ensure cost efficiency and, at the same time, meet customer expectations and requirements.

7.1.2 Product types and market requirements

As it was discussed in the literature review, an essential part in supply chain design is to match the supply chain type to product and market characteristics. Thus, an important starting point in the empirical study was to examine the product characteristics and market needs posed by the customers for the case company's products.

One of the oldest products in the offering are solar systems which have been available around five years. Systems are sold as turnkey solutions to consumers including all materials and components needed for a solar system to operate including solar panels, an inverter, roof mounting structures and other electrical material such as cables and fuses. In addition, installation and all required permits are included in the delivery. Based on the identified characteristics, solar systems are classified as hybrid products including innovative components (solar panels) and standard components (inverters, mounting structures and other electrical material). The demand for solar systems is constantly rising and the product is at the growth phase in the product life cycle. However, the challenge is that the demand pattern is highly seasonal concentrating over the summer months since roof installations are challenging during the winter due to snow and harsh weather conditions. According to the product manager, price is clearly the market winner for solar systems since customers are quite price sensitive and base their purchasing decisions on costs savings and lowest possible investment payback time that they achieve with the product. Product quality, on the other hand, is a very important market qualifier since solar systems are quite expensive and expected to last around 25-30 years in use.

EV home chargers are a quite new product in the offering since they have been available for a few months and thus, in the introduction life cycle phase. As the name suggest, the product is used to charge an EV at home and it is typically installed on garage wall or on a pole in the driveway. The basic technology related to chargers is not new but frequent version updates and changing regulatory standards indicate that some innovative product characteristics are present. Demand is constantly rising due to rising sales of EVs and can be even predicted by using the number of EVs as a proxy. Thus, availability is a key market winner since home chargers are still rarely available especially in the Nordics and the number of EVs is rising fast. Quality and price are two important market qualifiers for these products.

Heating optimization products are one of the oldest products in the offering among solar systems and thus, in the growth life cycle phase. These products are used to optimize heating according to hourly electricity prices and customer temperature preferences, and consists of temperature sensors installed in the customer's home bundled with software. For these products, demand is growing and probably is also seasonal since customer needs typically arise during the winter when heating is most needed. However, it might that the seasonality is at least partly strengthened due to the increased marketing efforts and campaigns during the fall and winter. Product variety is low since only four variants are offered. As with the other products related to energy efficiency, price is the key market winner since product's value to customer is strongly linked to the achieved cost savings. Lead time, quality and availability are important market qualifiers for heating optimization products.

Batteries are still in the pilot phase and only a handful have been delivered to customers. Batteries enable the storing and using of energy when it is most beneficial for the customer. Demand is unpredictable since the market for energy storage is still developing influenced also by political decisions in the form of state subsidies and support programs. However, demand is expected to rise significantly in the future since renewable and decentralized energy production requires the ability to store energy. Current market prices are quite high and thus, price is also a market winner for the batteries since payback times are very long with current electricity prices.

In addition to standard ready-made products sourced from suppliers, the case company also has two products, an energy monitoring device and a smart home product, which are manufactured based on the case company's specifications using contract manufacturers in Europe. Both products resemble a standard product on certain attributes since their product life cycles are fairly long, product variety is low and manufacturing lead times are long. However, their demand is growing and is unpredictable indicating attributes of an innovative product. In addition, both products are at the introduction product life cycle phase as they have been available for only a few months. Price was found to be the market winner for both products while lead time and quality being important market qualifiers according to the product managers.

Table 11. Characteristics of consumer products

Attribute	Solar systems	EV home charging	Heating optimization	Batteries	Energy monitoring device	Smart home product
Demand	Growing and seasonal	Growing	Growing and seasonal	Growing and uncertain	Growing and uncertain	Depends on other products
Product variety	Low (< 10 variants)	Low (< 5 variants)	Low (4 variants)	Low (1 variant)	Low (1 variant)	Low (2 variants)
Product life cycle	Short (< 12 months)	Short (< 12 months)	Long (> 12 months)	Short	Medium	Medium
Manufacture/ sourcing lead time	1-4 weeks	4-6 weeks	1-3 months	3-4 weeks	2-6 months	3-4 months
Market qualifiers	Quality Availability Lead time	Price Quality Lead time	Lead time Quality Availability	Quality Availability	Lead time Availability Quality	Quality Lead time Availability
Market winner	Price	Availability	Price	Price	Price/cost	Price/cost

Consumer product characteristics are summarized in Table 11. Based on the discussion above, all products contain characteristics from both standard and innovative products. In one hand, product variety is low and manufacturing lead times long indicating towards a standard product. However, on the other hand, product life cycles are relative short, and demand is unpredictable and partly seasonal signaling characteristics of an innovative product. Thus, products can be classified to as hybrid products.

Most products build the customer value from cost savings in electricity and heating costs that the customer can achieve when using the product. Thus, customers place their purchase decisions heavily on the payback time and achieved savings. This has implications also for the case company's supply chain since cost efficiency in the chain becomes important in achieving higher profit margins and also to cope with increased price competition in the market. However, since some products have long production lead times, inventories are required to be maintained in the supply chain to meet unpredictable demand in terms of location, variety and volume. Thus, it is challenging to balance between cost efficiency and flexibility when planning and making decisions related to the supply chain.

7.1.3 Supply chain operations and challenges

After mapping the product types and market requirements, the current supply chain operations and related challenges were examined. Based on the interviews and discussions, three different supply chain models were identified depending on the number of external actors in the chain: (1) outsourced supply chain, (2) semi-managed supply chain and (3) fully-managed supply chain. These models were used at the case company depending on the product, product life cycle phase and market area where the product is offered.

The simplest model from case company’s supply chain perspective is the outsourced model presented in Figure 22 since it requires minimum material flow management from the case company. In this setup, the service provider is responsible for all material flows providing turnkey deliveries to the case company’s customers. In other words, service provider handles the sourcing of materials and related transportation, warehousing, distribution and finally, installation at the customer. The case company still has the ownership of customer relationships but everything related to material flows is handled by the service provider. One of the advantages of this approach is that there are no risks or capital tied to inventories for the case company. However, influence on material choices is lower compared to a situation where the case company would itself contract the material suppliers. The model is especially beneficial when expanding into new market areas or at the beginning of product life cycle since it is easier and faster to setup operations. Disadvantages include low visibility and control to the total supply chain, especially to the turnkey service provider’s suppliers i.e. lower-tier suppliers. In addition, risk of supplier lock-in and price increases are high due to working only with one supplier.

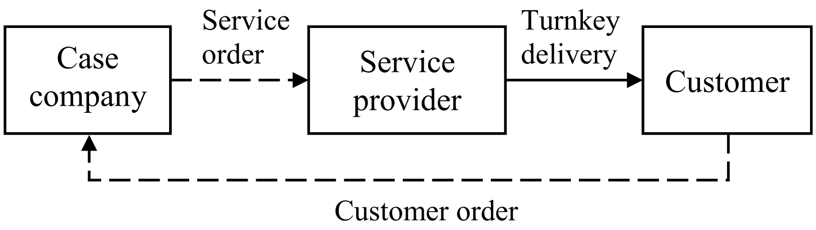


Figure 22. Outsourced supply chain at case company

Semi-managed supply chain model in Figure 23 is the most common model currently used at the case company. It differs from the outsourced model by dividing materials and installation services to separate providers. Materials are sourced from the material suppliers by the case company and transported to the installation company's warehouse. Thus, the installer handles warehousing and inventory management, and informs the case company when more inventory is needed. Installer is also responsible for the distribution and installation at customer's site. Similarly as in the previous model, the case company manages the customer relationships but now the material supply and installation services are divided to separate suppliers. Major advantages of this model are the increased control in the supply chain and ability to affect material choices since the case company is responsible for material sourcing. However, this model requires more work in material flow management and leads to low visibility to inventory levels since inventories are dispersed across installation service providers in different countries.

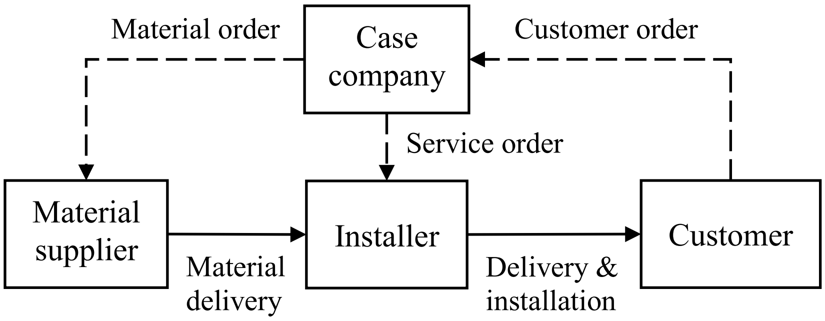


Figure 23. Semi-managed supply chain at case company

The third model, fully-managed supply chain, is presented in Figure 24. It is the most complex model from the case company's material management perspective since the chain operates with three different actors: material supplier, logistics service provider and installation service provider. Materials are first sourced from material suppliers and transported to the logistics service provider's warehouse. Logistics service provider handles warehousing and delivers products to customer site. Finally, the installation service provider performs the electrical installation of the product. This setup requires high management work and coordination since all parties in the supply chain must cooperate in order to provide high quality service for the customer. It is especially important that the logistics and installation service providers communicate effectively in order to have the materials ready at customer's site for the agreed installation date. Challenges in this model are high financial risks related to inventories for the case company, and the resources and time required to setup the operations and relationships with suppliers and service providers.

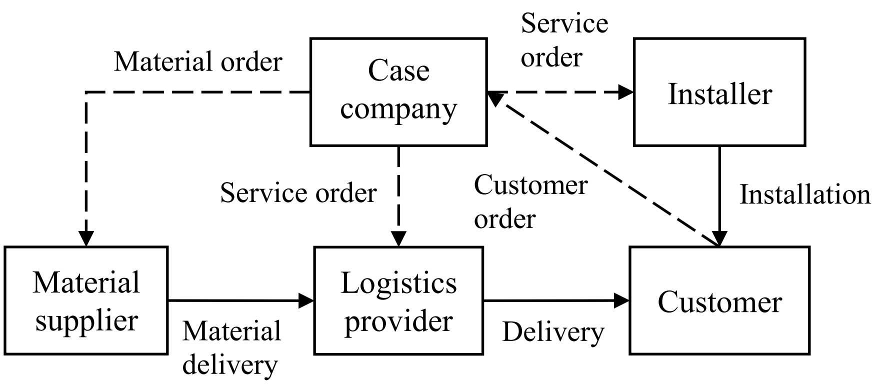


Figure 24. Fully-managed supply chain at case company

Advantages, disadvantages and suitable use environments of these three models are summarized below in Table 12. It was found that the outsourced model has mostly been used in new market areas where supply chain expertise and resources have been limited. In addition, difficulties in finding competent installation service providers or aligning the operations with suppliers have explained the usage of this model in some cases. The outsourced supply chain is fast and simple to setup and thus, an option when time-to-market and agility are critical. When suitable installation service providers have been available, then the semi-managed model have often been used. This model works well in the introduction product life cycle phase since the installation service providers still can handle the warehousing and distribution for low volumes. The fully-managed model has been used in the situation where volumes are higher and a separate logistics service provider is required for effective handling of warehousing and distribution. Thus, there seems to be a point in the product life cycle when it is best to switch from outsourced or semi-managed supply chain to fully-managed supply chain to enable cost efficient and effective supply chain operations when the sales volume reaches a critical point.

Table 12. Summary of three current supply chain models at case company

	Outsourced supply chain	Semi-managed supply chain	Fully-managed supply chain
Advantages	• No inventory risk/costs • Low material management work • Fast and agile operations ramp-up	• Increased control in the total supply chain • More influence on material choices	• High control in total supply chain • Cost effective with high volumes • Capabilities of logistics provider
Disadvantages	• Limited influence on material choices • Low supply chain visibility and control • Supplier lock-in risk	• Low visibility to dispersed inventories • Increased management and coordination work	• Resources and time needed to set-up • High management and coordination work • High inventory risk
Suitable use environment	• New market areas and products • Resources are limited • Time-to-market is critical	• Low volumes • Introduction and early growth product life cycle phase	• High volumes • Growth and maturity life cycle phases

Total supply chain network related to the consumer product offering is mapped in Figure 25. As can be seen, the network is quite complex containing many material suppliers, logistics service providers and installation companies making it difficult to manage the complete network. It is also worth noting that countries are working quite independently from each other and thus, common material suppliers and best practices have been hard to find. Thus, supply chain operations are not coordinated in a company-wide level considering the total supply chain but mostly in a country level or product level. Third, there are many inventories located at the installation service providers. Since there is at least one installer per country, inventories are dispersed in the supply chain network decreasing the visibility to inventory levels and affecting the ability to effectively control the inventories.

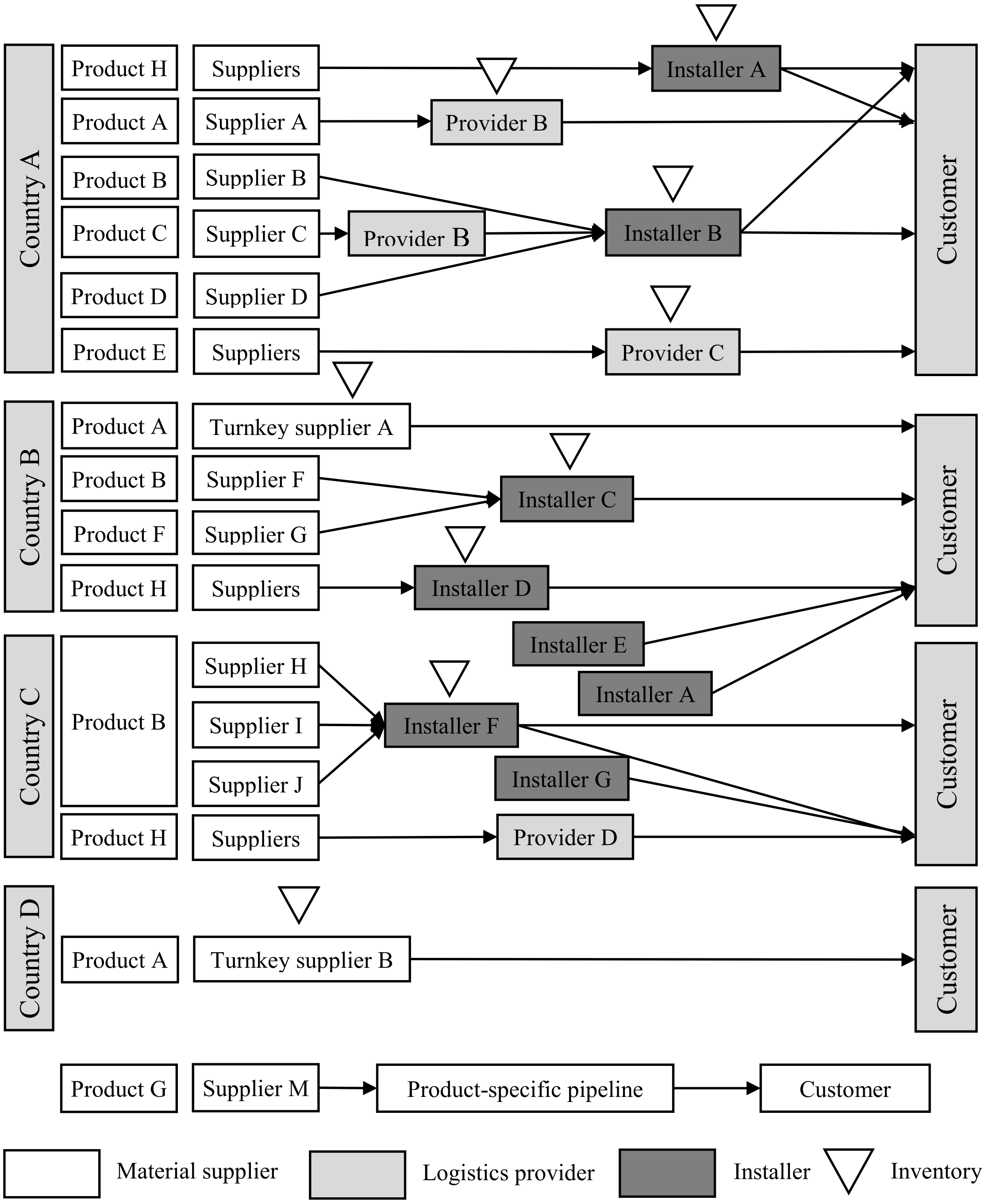


Figure 25. Total supply chain network at case company

Some of the challenges in current supply chains and operations were already discussed above but more elaboration is needed. It was found that challenges can be generally divided into three distinct categories: supply chain structure, organization and knowledge as summarized in Figure 26. Supply chain structure challenges are related to the actual configuration of supply chain including partner selection, decisions on warehousing locations and routing of material flows. Organization challenges, on the other hand, refer to the organizational factors such as organization structure, roles and responsibilities, and cooperation between functions in the supply chain context. Finally, knowledge-related challenges refer to the expertise and knowledge in the field of supply chain management both at strategic and operational levels.

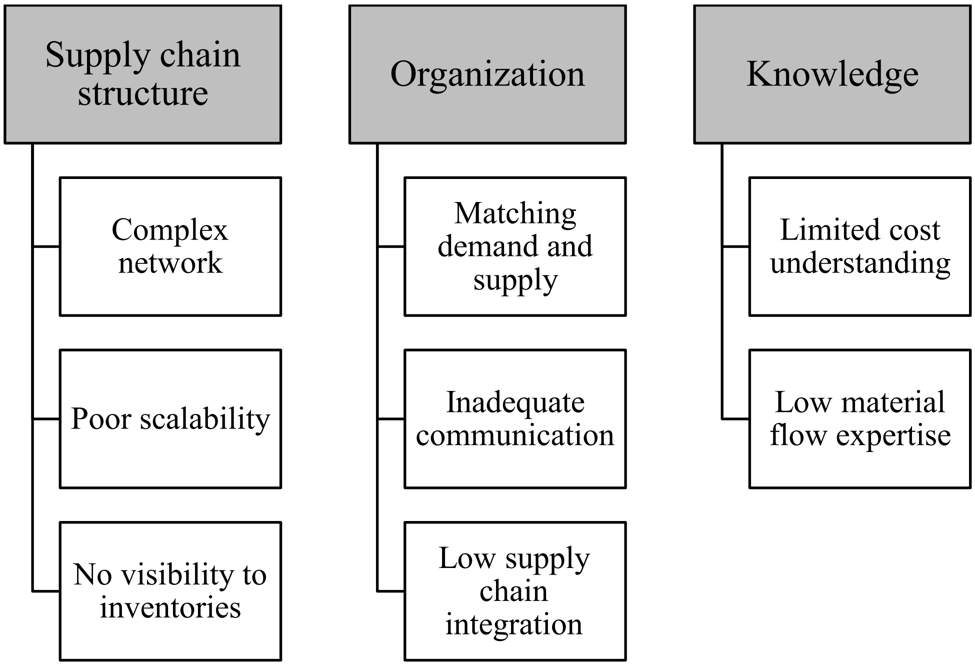


Figure 26. Supply chain challenges at case company

One of the largest challenges related to the supply chain structure is the complexity of the current network. As it was discussed earlier, three different supply chain models are used within the case company making it challenging to manage the total supply chain around the product offering. In addition, the network consists of many material suppliers, logistics service providers and installation companies across countries and products further complicating the network.. This results in extra work and probably extra costs for the case company.

The complexity has been the result of two main factors: development history of consumer product portfolio and geographically dispersed organizational units. Consumer products have been added to the portfolio over the last five years and each product have adopted a slightly different supply chain and thus, increasing the complexity of the network product by product. In addition, dispersed organizational units working independently have resulted in a situation where local offices have adopted their own practices and processes in the supply chain.

Due to the complex structure and many actors in the network, inventories are dispersed across the four countries making inventory control challenging. In addition, since most inventories are situated at the installation companies, visibility to the inventory levels is lacking since installation companies do not have systems for real time inventory level reporting. This makes inventory control and replenishment planning very difficult since the case company does not have real-time information about what materials are stored, where and how much. In addition to inventory level visibility, installation companies' capabilities to handle warehousing for higher volumes are questionable since logistics management is not their core competence. Thus, the scalability of current operations is poor when volumes increase.

The second category of challenges, organization, is related to the organizational structure, internal processes and communication. One major challenge related to this category is the difficulty of matching demand and supply of products. According to several product managers, this have caused many occasions when products have been out of stock or, in the other hand, inventory levels high compared to the actual realized demand. The major reason for this challenge is the low level of supply chain integration since functions and business units are mostly working independently focusing on their specific products and tasks not taking the total supply chain network into account in decision making. For example, communication between sales and purchasing including sharing demand forecasts to purchasing, and available stock and incoming material order information to sales in inadequate. In addition, demand forecasting processes are highly manual and planning horizons often too long reducing the ability of responding to rapid changes.

Another challenge related to the organization are the limited resources since there is no specific function for supply chain management both on the strategic and operational levels. In addition, roles and responsibilities related to the operational supply chain management in general are unclear and vary between countries and business management levels. Thus, there are challenges in planning operations and managing material flows in a higher level. This makes it very difficult to plan inventory replenishment, forecast total demand and to match demand with supply across products and countries since the total view on the supply chain is hard to establish.

Knowledge is the third category of challenges relating to the expertise and competence to manage material flows. As an energy utility company, case company's traditional core competence involves the generation and sales of electricity and heating through power lines and pipes. Thus, the competence to handle tangible material flows to consumer customers especially in terms of demand forecasting, inventory management and distribution need to be developed further. However, the case company has already discovered these limitations and initiated several developments projects with the objective of increasing supply chain knowledge and expertise. Due to the situation, it can be said that the case company is in a learning phase related to managing the supply chain operations since many important processes and practices are still being developed. In addition to expertise, total supply chain cost information is not easily available making it difficult to track overall supply chain performance and also to evaluate individual actors in the network.

7.2 Solution design

Literature review and empirical data collection and analysis built the foundation for the solution design. First, the literature review provided the basic elements and cornerstones for supply chain design and other important management activities required in the supply chain context. Second, the empirical part including identifying the product types, market requirements and challenges in the current supply chain operations helped to tie the solution to the actual context of the case company. This section discusses this process of solution design and development.

7.2.1 Requirements and objectives for solution

Before going to the details of the actual solution, requirements and objectives for the solution are discussed. In other words, what is the desired end state to be achieved with the solution (Holmström et al. 2009) as presented in Figure 27. Perhaps the most important objectives for the proposed supply chain model are scalability and flexibility. These are important since sales volumes are expected grow rapidly in the next few years for all products and market areas. In addition, it is crucial to have the ability to respond to changes both in demand volume and variety due to the uncertain and dynamic environment. Speed is also important since the case company is experimenting on several product concepts and thus, fast operation ramp ups and run downs are essential.

Second, cost efficiency and improved controllability are required for the supply chain. This was quite well emphasized by one interviewee stating: “we need to manage the supply chain rather than the supply chain managing and constraining us”. Additional objective is that the supply chain model would be company-wide at least in a high-level allowing using it for all products and market areas. Thus, it would be possible to replicate the same model whenever expanding to new market areas or introducing new products. Finally, it is crucial that the solution provides tools for managing the total supply chain taking into account activities such as purchasing, inventory management and distribution.

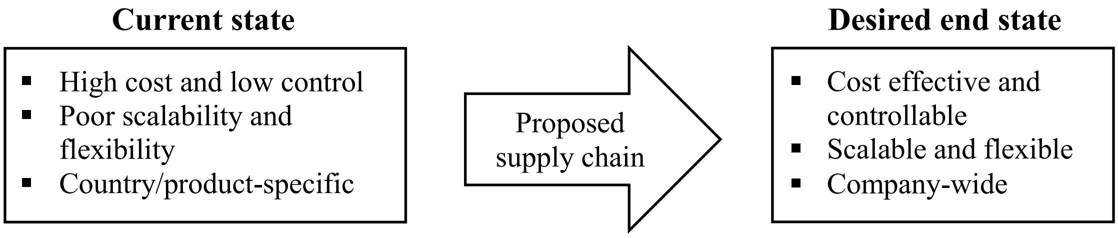


Figure 27. Requirements and objectives for the solution

7.2.2 Supply chain structure

Solution design was started on a strategical level by focusing on supply chain design and structural-related decisions. As it was identified earlier in this chapter, case company's consumer products are hybrid products combining characteristics of standard and innovative products. In addition, it is challenging to balance between the requirements for cost efficiency (price sensitive customers) and flexibility (uncertain demand). Thus, there is a clear indication that the proposed supply chain should combine lean and agile methods that achieve both efficiency and agility in the supply chain. Furthermore, since the case company purchases all materials and products instead of own manufacturing, it is natural that the order decoupling point method and strategic inventory positioning is used for combining lean and agile supply chains. This enables applying lean processes upstream towards suppliers to achieve efficiencies and, on the other hand, agile processes towards customers to improve the flexibility and agility in fulfilling the demand.

It was argued in the literature review that the degree of purchasing, manufacturing, logistics postponement determines the ODP position in the supply chain. The case company does not have own manufacturing which simplifies the problem leaving the purchasing and logistics postponement to be decided. Thus, there are three options:

(1) Purchase and deliver products based on customer orders (purchasing and logistics postponement)
(2) Purchase ahead of demand and deliver from a centralized location based on customer orders (purchasing speculation and logistics postponement)

(3) Purchase ahead of demand and deliver from decentralized locations based on customer orders (purchasing and logistics speculation).

However, since supplier lead times exceed delivery lead time requirements for most products, and high transportation and administration costs related to small and frequent purchases, purchasing and logistics postponement is not a viable option for the case company. As the result of the reasoning, two alternatives are proposed depending on the degree of logistics postponement: (1) central warehouse to supply all countries utilizing logistics postponement or (2) decentralized warehouses within each country utilizing logistics speculation.

In the centralized warehousing model presented in Figure 28, the idea is to hold strategic inventory and place the ODP at the central warehouse. Thus, lean supply chain with forecast-driven material push is used between the suppliers and central warehouse, and agile supply chain with demand-driven pull between the central warehouse and customer. Lean supply chain includes the utilization of economies of scale when transporting to the central warehouse (e.g. low cost and slower transportation modes, full truckload (FTL) deliveries and aggregated purchasing volumes). On the other hand, the agile supply chain towards customers utilizes faster transportation modes (e.g. package carriers and last mile deliveries) and smaller transportation lot sizes to achieve responsiveness and flexibility. Customers located at the same country than the central warehouse are supplied directly from the warehouse. However, with other countries, local cross-dock terminals can be used in order to merge material flows coming from and going to different locations.

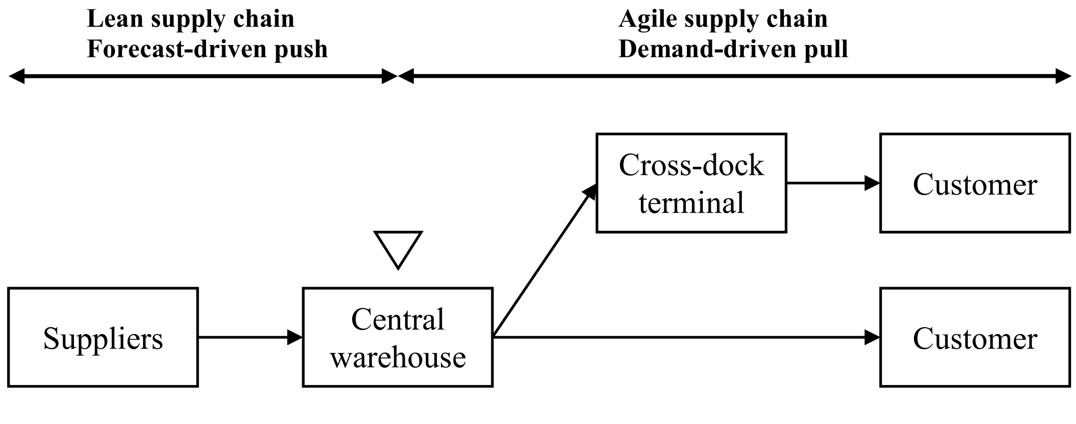


Figure 28. Central warehouse with logistics postponement

The major advantage of the centralized model is the economies of scale achieved in the supply chain by aggregating purchasing volumes into one location resulting in lower unit and transportations costs. In addition, central warehouse is easier to manage and control in the company-wide level since there is only one control point. Potential disadvantages include increased outbound transportation costs due to increased transportation distances to customer and decreased customer service levels. It was, however, pointed out in one discussion with a potential logistics service provider that major logistics providers have very effective networks within Europe and delivery lead times are measured in 1-2 days making it possible to achieve high service levels also from the central warehouse. More challenging is to forecast demand and set the inventory levels accordingly.

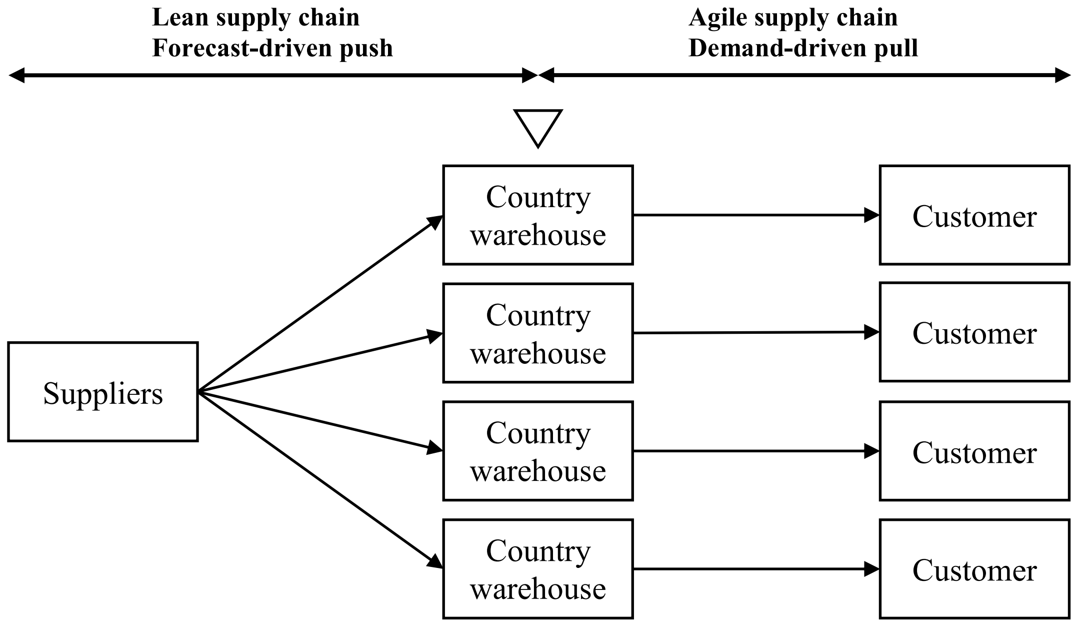


Figure 29. Country warehouses with logistics speculation

The second alternative, decentralized warehousing in Figure 29, speculates logistics activities and supplies customers from country warehouses located close to the customers. In other words, products are transported to regional warehouses based on forecasts and linked to actual customer orders in the country level. Thus, ODP is placed at the country warehouse, lean processes used until the warehouse and finally deliveries to customer from the country warehouse handled with agile methods. The advantages compared to the previous alternative are increased customer service levels and slightly decreased response times as inventories are located closer to the customers. However, due to the higher amount of warehouses, inventory handling and holding costs are higher. In addition, economies of scale at the supply side are limited since material flows are divided between four destinations. Due to the logistics speculation, this alternative also requires reliable demand forecasting and if not done effectively, risks of excess inventory or stock outs are high especially if material transfers between the country warehouses are not planned on time. Finally, the work of managing and controlling four separate warehouses is higher leading to lower supply chain controllability compared to the previous model as there are more control points in the supply chain.

7.2.3 Logistics

The foundation of the logistic operations in the proposed solution is based on using a logistics service provider for transportation and warehousing activities. Owning or leasing warehouse facilities and a fleet of transportation vehicles is not practical since logistics operations are not a core competence for the case company and logistics services are commonly available to be purchased in the market. Thus, it is justified to use a separate logistics service provider. A competent logistics service provider with global operations and a wide network of partners will enable more options in facility locations and transportation modes leading to scalable and flexible logistics operations.

As it was addressed in the previous section, lean supply chain should be utilized upstream from the ODP (inventories) towards suppliers. From the logistics perspective, this is related to material flows from the suppliers to the case company's warehouses. Achieving economies of scale should be the primary focus related inbound transportation which is achieved best in the centralized warehousing since all materials flows are consolidated into one location. Using a logistics service provider leaves more options for the supplier deliveries since currently the case company has relied completely on supplier-offered logistics. In the proposed solution, the case company has the option to handle the inbound transportation using the own logistics service provider if rates are lower. In addition, importing from low-cost countries in Asia will probably increase in the future and a logistics service provider can offer services for importing and handling the formalities such as taxes and customs.

An important focus area between inbound transportation and outbound distribution is inventory management. Decisions in this area are related to determining inventory levels, and order quantities and timings for replenishment orders. A major advantage in both proposed alternatives (centralized and decentralized) is the increased visibility to inventory levels. In addition, inventory control and coordination of replenishment orders between products is much simpler when there are fewer inventories in the supply chain. A starting point would be to focus on traditional inventory control models by integrating the case company's internal functions and activities in inventory replenishment. As seen in Figure 30, demand data in the form of committed orders and demand forecasts is an important input for inventory control. Thus, it is proposed that the case company starts a systematic and regular sharing of demand data both in terms of forecasts and confirmed orders to be used in inventory control. Later, it is possible to develop collaborative inventory models that also consider the external actors in the supply chain in order to utilize information such as supplier available capacity and capacity forecasts in inventory control decisions. Since many of the case company's major suppliers have intermediate storage facilities in central Europe allowing short delivery times, one option in the future could be to increase the suppliers' responsibility in warehousing resulting in less warehousing need for the case company.

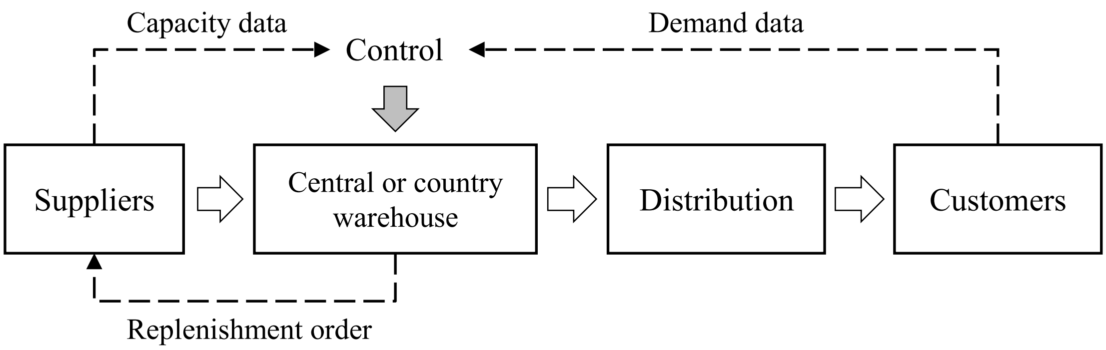


Figure 30. Process of inventory control with main inputs and outputs

In contrast to the lean and efficient inbound transportation processes, distribution activities are focused to the demand side by fulfilling actual customer orders. Thus, this side of the supply chain must be more agile, responsive and flexible compared to the supply side. Two parallel distribution channels presented in Figure 31 are proposed depending on the product to enable agile distribution network:

(1) Direct delivery from inventory location to customer for large products
(2) Delivery routed via the installation provider for small products

The same logic applies both in centralized and decentralized warehousing alternatives i.e. products are distributed from the central or country warehouse. The reasoning for the two-channel approach is as follows. First of all, large products e.g. solar systems and charging stations are more effectively handled by the logistics service provider directly to the customer site since they require delivery on pallets due to high weight and size of the shipment. In addition, these type of products are often weatherproof allowing them to be delivered to the customer's yard one day before the installation.

However, most of the consumer products are small, under 5 kg and parcel size packages, enabling delivery with vans and smaller distribution vehicles. Since the electrical installation is at any case required at the customer, it is practical that the small-scale products are first shipped to the installation company's intermediate warehouse. Thus, the final distribution is carried out by the installers at the same time when traveling to the customer to perform the installation. Furthermore, since some of the products can be installed without the customer present at the site, it is more reasonable that the installers handle the final distribution and delivery to customer. It is not reasonable to ship single products to the installation service provider's warehouse but can be shipped in batches for example once a week for the next week's confirmed installations. In addition to shipping the small products to the installer, decentralized country warehouses allow customer pick-ups as one delivery option.

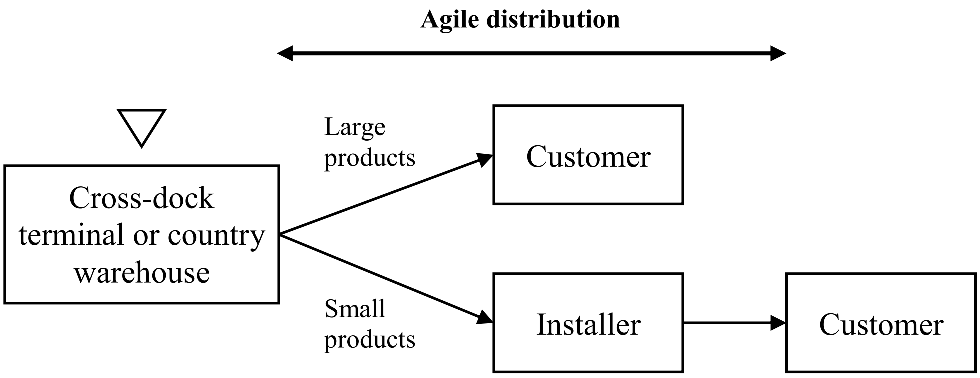


Figure 31. Agile distribution network

7.2.4 Supply chain management

First, a few proposals are given for purchasing and supplier base management. Supplier base consolidation is an important first step since common material suppliers for all countries will increase the purchasing power but also enabling economies of scale through higher purchasing volumes resulting in lower unit prices and transportation costs. In addition, it is easier to manage the supply base and supplier relationships when there are fewer suppliers.

It is also important to investigate and utilize existing supplier relationships and contracts as much as possible to achieve synergies between consumer and commercial offerings since the case company also has suppliers delivering modules for large-scale solar plants and public EV charging stations. Finally, although it was just emphasized to consolidate the supplier base, local second source suppliers e.g. distributors or manufactures that can supply products with shorter lead times in the case of surge demand and sudden stock outs should be taken into account.

Part of the solution is also to start a systematic demand and supply planning process. As can be seen in Figure 32, there are four key persons participating in this process: purchasing manager, product manager, service manager and sales manager. Purchasing manager has the overall responsibility of the supply side e.g. supplier selection, negotiating and managing the contracts. On the other side, sales manager is responsible of sales and interacting with the customers. Service manager handles the service partners, logistics and installation, in order to ensure high-quality service provision. Finally, the product manager has the responsibility over the product offering. This setup is still missing one important element which is related to the operational activities and management of the complete supply chain.

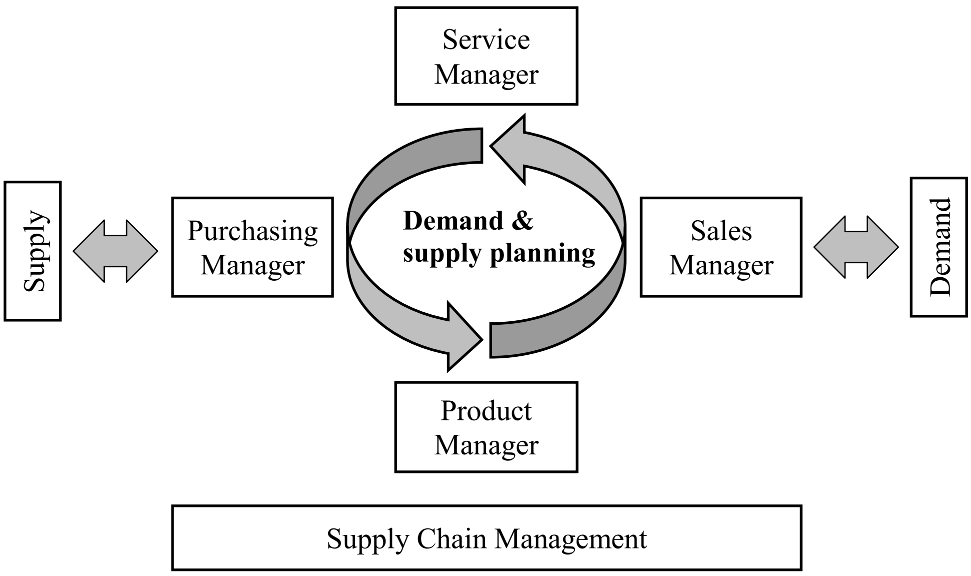


Figure 32. Demand and supply planning process

Thus, it is proposed that a separate function for supply chain management is established. This function would have the overall responsibility of the supply chain across all products, functions, countries and would be responsible for example transportation optimization, inventory control and replenishment, distribution operations and supply chain performance evaluation. A simple and concrete action would be to start regular demand and supply planning meetings facilitated by the function and participated by the four persons described above to share information and plan on three areas: (1) review past deliveries and performance, (2) review order backlog, confirmed orders and available inventory and (3) update forecasts and decide actions to fulfill future demand.

Supply chain integration is a wide concept as it was addressed in the literature review but the focus here in more on the information systems enabling end-to-end supply chain integration i.e. allowing efficient sharing of information and collaborating with external actors in the network. Figure 33 presents the current capabilities and directions for improvement related to supply chain integration at the case company. Supply chain integration is already established in the downstream supply chain between the case company, installation service provider and customers. A system is used for collecting confirmed customer orders, sending service orders to installers and managing the order-installation process from the customer's side.

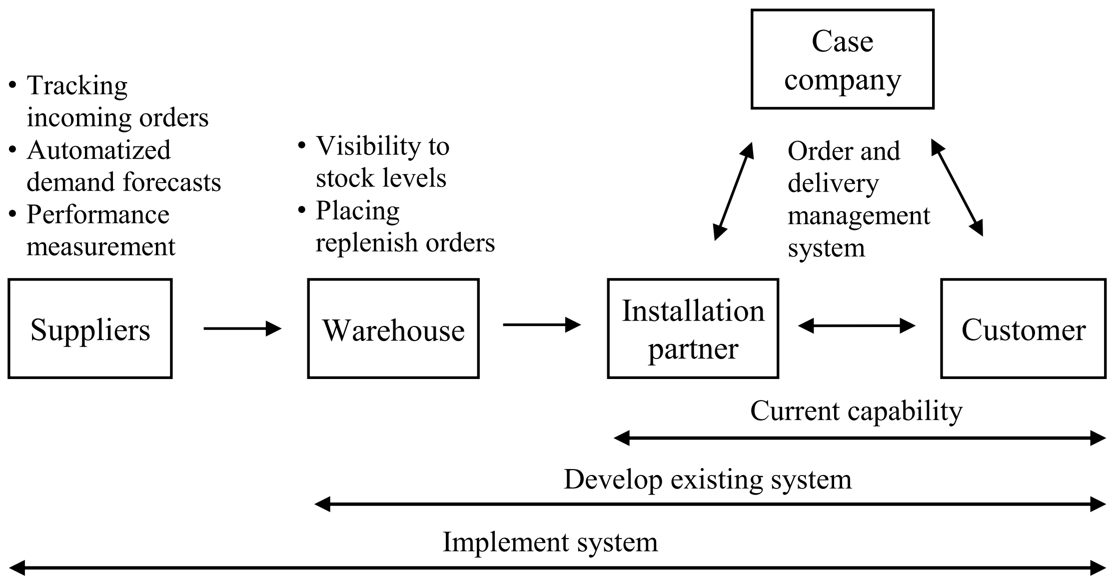


Figure 33. Information system perspective on supply chain integration

It is proposed that the integration is extended more upstream in the supply chain towards logistics service providers and material suppliers. A development project to implement an asset management software including inventory management capabilities in the consumer products supply chain had already been started in the case company. Thus, it is probable that supply chain integration will soon also cover the inventories resulting in the ability to review inventory levels and place replenish orders to suppliers in an electronic format or even automatically triggered according to stock levels. However, completely lacking is the integration to the farthest point upstream towards suppliers. It is not possible for example to automatically track incoming and in-transit orders from the suppliers. In addition, automatic information sharing in the form of demand and capacity forecasts between the case company and its suppliers is not possible and thus, increasing supply risks and affecting planning capabilities. It is recommended that the case company implements an information system that also reaches the suppliers enabling end-to-end supply chain integration.

Final element in the proposed solution is related to supply chain performance measurement systems. It was stated in the literature review that the measurement system should always be linked to the supply chain strategy and goals. Thus, there has to be a linkage between the selected metrics and supply chain goals. In addition, it was emphasized that best performance metrics capture the complete supply chain enabling the evaluation of overall supply chain performance. The foundation of the proposed performance measurement system in Figure 34 is related to the supply chain phases in SCOR model (Lockamy & McCormack 2004) with a modification of make phase replaced with store phase since the case company does not have manufacturing activities.

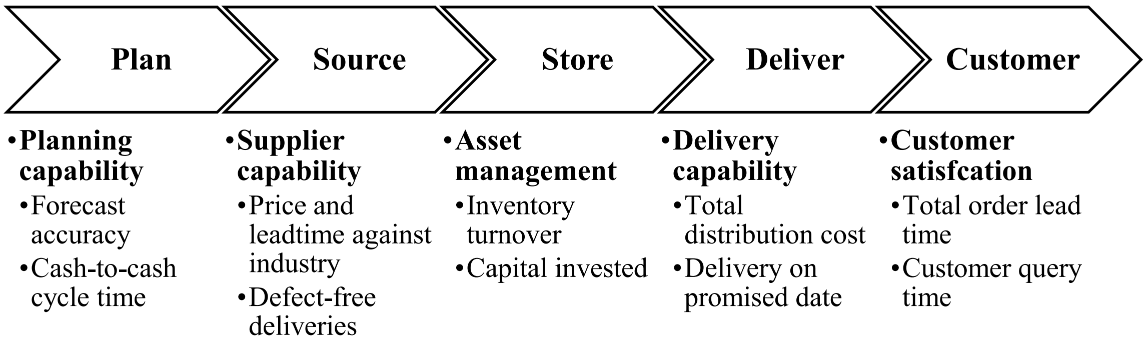


Figure 34. Supply chain performance measurement system

Performance measurement in the plan phase concentrates on evaluating the planning capability in the supply chain. This is especially important for the case company since purchasing based on forecasts is required due to long supply lead times and unpredictable demand in the marketplace. Thus, forecast accuracy is a suitable metric to evaluate the case company's capability to forecast demand and plan supply chain operations based on those forecasts. Cash-to-cash cycle time (time between inventory purchase and account receivables collected for the sale of that inventory) is another useful metric since it illustrates the supply chain's ability and effectiveness to generate cash flow by turning purchased inventory into revenue from customers.

Source phase involves selecting suppliers and sourcing of materials and thus, supplier capabilities are crucial for supply chain performance especially due to the purchasing-intensive operations of the case company. Due to this reason, it is not possible to seek cost and lead time reductions in manufacturing processes. Thus, suppliers are the main source for these improvements, and benchmarking supplier prices and lead times against industry is one method for evaluating supplier capability. In addition, defect free material deliveries are highly important since malfunctioning electrical products can lead to major safety risks for customers and high costs to the case company when having to replace and reinstall defective products.

Performance in the store phase relates tightly to asset management or, in other words, the capability of the case company to manage its inventory assets in the supply chain. Poor inventory replenishment planning and high inventory levels have caused problems for the case company and thus, effective inventory management should be in focus. Inventory turnover (number of times inventory is consumed in a time period) and capital invested in inventory are selected as performance metrics for this phase since they capture the essence of efficient inventory management and lean material flows.

Similar than in the source phase, the case company relies heavily on external partners in the deliver phase. In other words, logistics service providers have an important role in reliable and cost effective customer deliveries. Total distribution cost as a metric captures the supply chain's cost efficiency. Reliable deliveries are also important since materials are required at the customer's house on an exact date for installation. Missing materials may lead to high costs when compensating lost working hours to the installation companies. Thus, the number of deliveries on promised date is selected as another metric.

Finally, metrics for customer satisfaction should be considered since the primary goal of the supply chain is to provide value for the customers. Total order lead time (time between customer order and final delivery) is one important metric since it captures the performance of the whole supply chain in fulfilling demand and, at the same time, influences directly on customer satisfaction. In addition, it was found that customers value fast responses when requesting quotes for products resulting in a risk of losing sales due to long response times. Thus, query time (response time to first customer contact) is another suitable metric for customer satisfaction.

7.3 Solution evaluation

The proposed solution was evaluated in two stages: (1) in an iterative process parallel to solution development in the middle phases of the study focusing on evaluating and improving the initial solution and (2) presentations to key decision-makers and managers at the case company in the last phases of the research when the solution was more refined. The iterative evaluation process together with the case company's thesis instructor was started after the initial solution was constructed in order to develop the solution further before presenting it to a wider audience. Regular meetings and discussions provided frequent feedback on the solution and led to several incremental improvements such as linking the solution more to the case company's context and adding elements that the researcher had not yet considered. For example, requirements for supply chain integration in terms of IT systems and system integration were taken into consideration based on this iterative evaluation process.

In addition to the iterative evaluation process, solution was evaluated in three sessions together with key decision-makers and managers including purchasing managers, product managers and business managers in order to obtain feedback and evaluate the applicability of the solution. It can be said that the solution was accepted and agreed to be applicable in a general level since most people agreed the problematic and unsustainable state of the current situation and that a solution is clearly needed. Participants also agreed that the proposed solution would most likely solve majority of the problems and challenges currently in the supply chain network by increasing the visibility and controllability of the network.

Majority of the concerns for the proposed solution in the three sessions were related to the actual implementation of the solution and what will it actually mean in practice for the case company. In other words, product managers from different countries would have hoped for more concrete description of the solution for their specific products and countries by presenting the supply chain processes and practices in a more detailed level. In addition, some participants commented that it would have been interesting to measure the solution's impact on supply chain costs. This would have also helped in reasoning the solution's importance to decision-makers when making decisions about solution implementation. Finally, it was pointed out that the solution might not be possible in all countries since based on previous experience, there have been difficulties in finding installation service providers due to the small installation volumes of the case company.

Based on the discussion above and despite some of the concerns, it can be said that the solution passed the weak market test defined by Kasanen (1986) since managers were willing to take solution into account in their future decisions. However, this was the only test passed since the next level, semi-strong market test, requires the solution to be widely adopted by companies and thus, not achieved in the scope of this thesis. In addition, requirements for the strong market test are even stricter since it requires the solution to produce better financial results compared to a situation where the solution is not used.

In addition to three evaluation sessions and applying the market tests, a qualitative comparison of the current state and two proposed supply chain structures was conducted by the researcher as presented in Table 13. This was a high-level qualitative comparison since evaluating the operational or financial performance of the solution was not possible in the scope of this thesis since implementing the solution would require significant resources, both in time and personnel. In addition, even quantifying the operational or financial performance of the current situation is challenging due to the fragmented supply chain operations making it complex to collect data and evaluate the total supply chain costs and performance.

Table 13. Comparison of current state and proposed solution

Variable	Current situation	Centralized warehousing	Decentralized warehousing
Costs	High	Low	Low to medium
Delivery lead time	Short	Short to medium	Short
Service level	Medium to high	Medium	High
Supply chain control	Low	High	Medium
Implementation effort	None	High	High

The alternative focusing on centralized warehousing probably is the most cost effective since inventories are consolidated into one location reducing the costs of holding and handling inventory. In addition, aggregated purchasing volumes allow full truckload (FTL) deliveries to the central warehouse resulting in lower transportation costs per unit. Current supply chain would be the highest in cost due to the lack of visibility and high management work required in the network. Alternatives do not differ significantly over the delivery lead time since major logistics service providers have wide and effective networks within Europe and can handle deliveries in a few days. Service level is highest with decentralized warehousing since inventories are located close to the customer but other alternatives are close due to the short delivery times. Control in the inventories and material flows is definitely the highest with centralized warehousing since single warehouse is easy to control and manage. Finally, the required efforts and resources to actually implement one of the proposed alternatives are high since the partnerships, supply chain processes and practices, and information systems are needed to be built for the majority of the products.

Part III - Contribution

8 Conclusions

This chapters concludes and evaluates the study. First, the findings are reviewed and practical implications discussed. Next in the theoretical contribution, the findings and proposed solution are discussed from a theoretical perspective by assessing the theoretical contribution of the study. Third, the study itself is evaluated based on its validity and reliability, and limitations are discussed. The chapter ends by suggesting directions for future research.

The aim of this study was to examine how a non-manufacturing company should design and manage a supply chain in an environment where it has limited experience and competence on consumer customer material flows. Design science research approach with a case study in a Finnish utility company was used for solving the research problem. As a result, concrete guidelines and decision factors related to supply chain design and management were identified and a solution proposed to the case company's practical problem to be utilized in a purchasing-intensive supply chain environment.

Supply chain design process starts by analyzing the supplied product types, customer needs and marketplace characteristics since supply chain strategy should always be linked to the firm's context. After analyzing the context, it is important to consider the supply chain type. For hybrid products combining elements from functional and innovative products, it was found that they are best matched with a leagile supply chain type that uses both lean and agile processes in the same supply chain. A suitable method for non-manufacturing companies to combine lean and agile supply chains is through the order decoupling point (ODP) by separating lean and agile processes in the supply chain.

Once the supply chain strategy and related supply chain type are selected, the actual supply chain structure has to be considered. For non-manufacturing companies with purchasing-intensive operations, the supply chain structure is mostly determined by degree of purchasing and logistics postponement which further impacts warehouse facility and distribution channel choices. Two alternatives were found applicable for the case company: centralized warehousing relying on logistics postponement or decentralized warehousing relying on logistics speculation depending on the service level chosen to be offered to the customers.

Final element is to define and implement the processes for supply chain management in order to effectively coordinate the material flows and activities in the supply chain. Inventory management was identified especially important for the case company since long supply lead times require the case company to maintain inventories to ensure product availability for the customers. In addition, end-to-end supply chain integration towards both suppliers and customers was found to be crucial for the case company since offering high customer service requires the coordination of efforts between the case company and its suppliers. Finally, a performance measurement system with suitable metrics capturing the total supply chain should be created to enable continuous evaluation and improvement of the supply chain.

The solution provides several potential benefits for the case company. First, by following the steps during the research process that were discussed above, the supply chain knowledge of the case company increased significantly. In addition, since the proposed solution will reduce supply chain echelons and simplify materials flows compared to the previous situation, the management and coordination work required from the case company will be reduced greatly. Finally, the solution enables the utilization of economies of scale both in purchasing and transportation most likely resulting in lower total supply chain costs.

It is also important to consider the next steps for the case company in order to implement the proposed solution in practice. This includes three key steps as presented in Figure 35:

(1) Deciding supply chain structure
(2) Determining exact requirements and specifications for logistics
(3) Establishing supply chain management

First of all, the degree of logistics postponement should be decided which determines the final supply chain structure being centralized or decentralized in terms of warehousing locations. It was found that the required customer delivery lead times are not a constraint for using centralized warehousing but if higher service levels are required, decentralized warehousing is an alternative option.

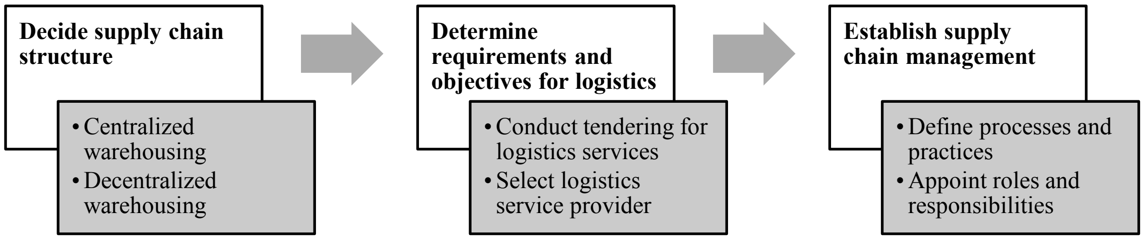


Figure 35. Practical next steps for the case company

In the second step, the exact requirements and needs for logistics should be determined. This is an important input for the tendering of logistics services since a competent logistics service provider with a global network and wide range of facilities and transportation mode choices is essential for effective logistics. Finally, once the structure is decided and logistics provider selected, focus should be on supply chain management including defining the processes and practices, and appointing separate resources for supply chain management.

8.1 Theoretical contribution

The two explanation phases of the design science research process presented in Figure 36 focus on demonstrating the theoretical contribution of the solution and generalizing the findings. This section discusses theoretical contribution while generalization of the findings is evaluated in the next section. Since only one case was used, theoretical contributions are restricted to the explanation I phase or, in other words, substantive theory was formed limited to the empirical context of the case company. Moving to the explanation II phase would require research with multiple cases including companies from different industries and supply chain environments.

Figure 36. Explanation I and II phases of the design science research process (Holmström et al. 2009)

The theoretical contributions of the study can be divided into two main areas. First, the study partly confirms existing theory in the fields of supply chain design and management for manufacturing firms by showing that specific key elements of existing theory can be applied successfully in the context of the case company. Thus, it seems that theories formed based on case studies conducted in experienced manufacturing companies can be applied to some degree also in a non-manufacturing company with limited experience related to consumer customer material flows by focusing on specific areas crucial for this environment such as inventory management and establishing the basic processes for supply chain management.

Second, the study forms new substantive theory in the context of the case company. This was done by identifying the most important elements and decisions related to supply chain design and management in the specific operational environment of the case company. Thus, new theory is formed and knowledge gap filled related to major elements and decisions in supply chain design and management for companies focusing in sourcing ready-made products instead of having own manufacturing activities in an environment where the company has limited previous experience on managing materials flows to consumer customers.

8.2 Evaluation and limitations

As it was already described in the beginning of part II, the credibility of any research is evaluated using the concepts of reliability and validity. For evaluating case study quality, four focus areas have been proposed: internal validity, external validity, construct validity and reliability (Yin 1994). Validity in this study was ensured with three main methods: (1) using multiple evidence sources, (2) linking evidence into a chain and (3) having informants review the case study draft.

Multiple sources of evidence were used in the forms of stakeholder interviews, observations in several meetings and discussions, and internal company material. In addition, multiple interviewees per product were selected to obtain information from several perspectives and organizational functions such as purchasing, business development, product management and sales. Evidence was linked together by following the planned research process and establishing links within the evidence e.g. between findings from different interviews or between interview evidence and observations. Finally, draft of the case study report was also reviewed by the case company's thesis instructor in order to increase the validity of the research.

On the other hand, reliability was established with using a case study protocol which included planning the research process and data collection methods in advance before starting the empirical study. Interview structures with pre-defined themes and open-ended questions were used to allow systematic data collection. In addition, interviews were recorded and transcribes which formed a case study database for the study which further improved the reliability of the study.

Since the design science research approach combined with a single case study was used, the research was highly focused on solving a practical problem with a solution tailored to the case company's environment and context. Thus, there are limitations in generalization of the findings to a wider context supported also by Yin (1994) arguing that a major problem in single case studies is the generalization of the findings. This leads to the conclusion that the findings can be generalized to a narrow area of supply chain design and management in a specific environment with the following characteristics: (1) operational focus on sourcing instead of manufacturing, (2) limited experience in managing materials flows to consumer customers and (3) products requiring works at customer site.

8.3 Further research

Since the present study focused on supply chain design and management more in a strategical level, one direction for further research would be to implement the proposed solution at the case company and evaluate the effects on supply chain performance and costs. In addition, the supply chain implementation process at the case company could be studied more in detail perhaps by identifying potential problems and practical guidelines how to be successful in the implementation. Finally, once the supply chain is implemented, one research area would be to study the operational processes and activities in the supply chain and their effect of supply chain performance in the case company's context. Thus, the following research questions are proposed to guide further research:

- What is the impact of the proposed solution on case company's supply chain performance and costs?
- What are the potential challenges and risks in supply chain improvement implementations and how to mitigate their effect?
- What concrete processes and activities are required to enable effective supply chain management and improve supply chain performance?

In order to reach the explanation II phase of design science, the research scope should be extended to cover other companies in the energy industry but also other industries since this study is limited to the explanation I phase by forming informal theory in the context of the case company. Thus, case studies including multiple case organizations from different industries are required to reach the explanation II phase. This would lead to formal theory that can be generalized to wider scope rather than limiting to the case context in this study.

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Appendices

Appendix A: Interview schedule

Date	Topic	Interviewee(s)	Duration
24.5.	Consumer product purchasing and suppliers base	Purchasing Manager A	40 min
4.5.	Solar offering and operations in Finland	Product Manager A	50 min
26.5.	Energy storage offering and operations	Business Development Manager A	40 min
29.5.	Energy monitoring product offering and operations	Business Development Manager B	40 min
30.5.	Heating optimization product offering and operations	Product Manager, B	35 min
31.5.	Consumer product logistic operations and logistics service providers	Purchasing Manager B	40 min
1.6.	Solution objectives and desired end-state for supply chain	Procurement Area Head A	30 min
1.6.	B2B EV charging purchasing	Purchasing Manager C	40 min
2.6.	Smart home product offering and operations	Business Area Head A	40 min
6.6.	Energy storage and energy monitoring product offering and operations	Business Area Head B	60 min
7.6.	Consumer product offering and customer needs	Product and Delivery Head	45 min
9.6.	Home EV charging offering and operations in Finland	Product Manager C	35 min
9.6	Product installations and installation service providers	Service Manager A	50 min
12.6.	Home EV charging offering and operations in Norway	Service Manager B	40 min
12.6.	B2B solar project purchasing	Procurement area head B	45 min
12.6.	Product offering and operations in Poland	Business Development Manager C	35 min
19.6.	Product offering and operations in Poland	Product Manager D	30 min
21.6.	Solar product offering and operations in Sweden	Product Manager E	35 min
29.6.	Smart home product offering and contract manufacturing	Technical Advisor	30 min
5.7.	Solar product offering and operations in Sweden	Product Manager F (former)	30 min
13.7.	Consumer product sales	Sales Manager	40 min

Appendix B: Stakeholder interview structure

Background info

- Name and position?
- What are your main responsibilities and tasks?
- How long you have worked at the company and how long in current position?

Product and service offering currently

- Describe briefly the products in your area
- How long the products have been available to customers?
- What is the business model for the products?
- What challenges there are with the current situation?

Customer needs and requirements

- What are the customer needs?
- What is most important and valuable for the customer?
- How important delivery time is for customers?
- How satisfied customers are for the products?
- What are the most critical elements affecting customer satisfaction?

Product characteristics

- What is the size of the product (dimension and weight)?
- How long is the product life cycle?
- How sensitive are the products in transportation and for weather conditions?

Purchasing

- Who is supplying the products?
- What kind of agreements there are with the suppliers?
- What is the typical lead time for orders from suppliers?
- How flexible the supplier is to cope with changes in order volume or schedule?
- How operational purchasing is handled?

Demand

- What is the demand for products (e.g. yearly or monthly)?
- Is the demand stable or is there seasonality?
- How predictable demand is?
- What kind of demand forecasting processes do you use?
- How demand is going to develop in the future (short, mid, long-term)?

Pricing and costs

- What are the direct and indirect costs related to the product?
- What are the prices for end consumers?
- How price sensitive customers are?

Transportation and warehousing

- What is the current logistics process for the product?
- Where are the products warehoused and what are the typical stock levels?
- What are the logistics costs (e.g. transportation and warehousing)?
- Do you have processes for reverse/return logistics?
- How do you cooperate with the current logistics service providers?

Delivery and installation

- What is the typical delivery lead time from customer order to delivery/installation?
- How important delivery time or performance is for the customers?
- What installation service providers are you using and what are the prices?
- How do you cooperate with the installation service providers?

Communication

- How do you communicate and cooperate with internal stakeholders (e.g. between business units, purchasing and sales)?
- How about with external stakeholders (e.g. suppliers and partners)?

Performance measurement

- What KPIs are you using to measure supply chain performance (e.g. related to suppliers, internal processes or customers)?